TS
330
K94
A214

# KRUPP

## A CENTURY'S HISTORY OF THE KRUPP WORKS

TS
330
K94
A21
+

Discipulus est prioris posterior dies

Cornell University Library
Ithaca, New York

White Historical Library
THE GIFT OF PRESIDENT WHITE
MAINTAINED BY THE UNIVERSITY IN ACCORDANCE WITH THE PROVISIONS
OF THE GIFT

Cornell University Library
TS330.K94 A21
+
Krupp.
3 1924 030 704 880
olin
Overs

18 SEP 1914
BISHOPSGATE, LONDON, E.C.

Date Due

MAR 5 1952
~~DEC 26 1956 H~~ S
APR 8 [illegible]
~~APR 21 1962 G Z~~
~~JUN 13 1963 M~~
~~[illegible]~~
~~DEC [illegible]~~
~~OCT 15 1981~~ F
~~MAR 1982 T~~
JAN 22 2007

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924030704880

# KRUPP

## A CENTURY'S HISTORY OF THE KRUPP WORKS

1812 1912

TRANSLATED FROM THE COMMEMORATIVE VOLUME
EDITED BY THE KRUPP WORKS

CORNELL
UNIVERSITY
LIBRARY

KB

# CONTENTS.

Page

Preface . . . . 1

FRIEDRICH KRUPP

- A century ago . . . . 4
- Small beginnings . . . . 12
- Struggle and failure . . . . 26
- Friedrich Krupp's life and character . . . . 37

ALFRED KRUPP

- 1826—1848 . . . . 42
  - Years of apprenticeship . . . . 43
  - The Zollverein . . . . 57
  - The spoon-rolling mill . . . . 67
  - Attempts on new fields . . . . 77
- 1848—1870 . . . . 88
  - Cast steel and the new age of traffic by land and by water . . . . 92
  - The cast-steel gun . . . . 114
  - From crucible to Bessemer and Martin steel . . . . 129
  - Evolution and organisation of the Works . . . . 145
  - Institutions for the welfare of the workmen . . . . 164
- 1871—1887
  - The commercial crisis of 1874 . . . . 174
  - The development of ordnance until 1887 . . . . 179
  - The Cast Steel Works during the last years of Alfred Krupp's life . . . . 199
- Alfred Krupp's life and character . . . . 210

FRIEDRICH ALFRED KRUPP

- Friedrich Alfred Krupp's life and character . . . . 245
- The Cast Steel Works from 1887 to 1902 . . . . 258
- The cast-steel gun since 1887 . . . . 272
- On new paths . . . . 288
- Social betterment institutions . . . . 302

THE WORKS SINCE 1902 . . . . 311

# PREFACE.

The laying of the foundation of the Firm of Krupp at Essen on the Ruhr as Cast Steel Works occured during those memorable years 1811/12. The first preparatory steps were taken towards the end of the year 1811, for in the November of that year the merchant Friedrich Krupp, with the intention "of erecting an establishment for the manufacture of English cast steel and of all products made thereof", set up the firm of "Fried. Krupp at Essen". At the same time he acquired a small water mill on the Berne, the so-called "Walkmühle" or "Halbachsmühle", to the north of Essen, near Altenessen, where he intended establishing his new works. The actual carrying into execution of the plan was begun at the outset of 1812; in the January of that year, the first practical experiments aiming at the making of cast steel were carried out in a house still existing:—number 17 of the II. Weberstrasse in the heart of ancient Essen. The erection of the works themselves, which were to comprise a foundry and a forge, was begun in the spring of 1812 at the Walkmühle. It was not till several years later that the first buildings of the present works, situated to the west of Essen, were put up, among which was the "Stammhaus", the primitive home of the Krupps. A few months after the foundation of the firm, on the 26th of April 1812, the first son, Alfred, was born to the young owner of the works. It was this son who, after the premature death ot his father, was called upon to lift his works out of the state of narrowness and failure, and raise them to the position of one of the greatest industrial enterprises of their time. During the whole of their hundred years' existence, the Krupp works have remained the personal property of the family of the Krupps. This is the case still in these days, even after they have adopted, as a mere outward form, that of a joint-stock company, in the year 1903, after the, alas, too early death of Friedrich Alfred, the third of the Krupps. The firm of Krupp therefore can commemorate this day in a threefold way, they can celebrate:

a century's existence of the Firm of Krupp and the Cast Steel Works at Essen,
the hundredth recurrence of the birthday of Alfred Krupp, whose name and genius are indissolubly connected with the rise of the works, and
the centenary union between the Works and the Krupp family.

This union, this collaboration never interrupted during a whole century, this unintermitted direction of the works by members of the Krupp family, have proved to be of the utmost importance for the development of the works. They have established that firm tradition which is a guarantee for the cohesion of the whole, for the concentration of all means and forces constantly kept directed upon the one aim, the furtherance of the works; they safeguard the independence of the works on all sides; they have at all times contributed to strengthen the feeling of fellowship among all classes of those employed in the works, keeping alive in them the feeling that they all collaborate for the good of one great whole.

The history of the Krupp works during the hundred years of their existence reflects the economic, political and intellectual development of the German people all along this period. What contrasts, the beginning and the end of this century! And what development within this epoch! In the one instance, a mechanic's workshop growing into the gigantic world-renowned enterprise of our days, in the other instance, a once powerful people, thrown into impotence through disunion, uprisen and joined together into the powerful German Empire. And in both cases the enormous rise of these last decades was preceded by a hard struggle, gradually leading to a slow ascent, and which continued down to the 'sixties of the last century. The first of the Krupps—born 1787, deceased 1826—was denied success in spite of all his pains and sacrifices. A vain struggle against unfavourable circumstances consumed his health and his means. Friedrich Krupp died not forty years old, and left his fourteen years old boy Alfred little more than the secret of making cast steel. Also Alfred Krupp—born in 1812, deceased in 1887—had to pass through the long schooling of hard and self-denying work. For many a decade he had to fight amid want and care, till at length, yet slowly, some faint success was attained. As late as 1848, when Alfred Krupp took over the works as sole proprietor, that is 36 years after their foundation, he only employed 70 workmen. In remembrance of such small beginning Alfred Krupp in 1873 wrote under a picture of his early home these touching words:—

"Fifty years ago this primitive workman's cottage was the refuge of my parents. "Would that any one of our workmen were spared the grief that the foundation of these "works brought upon us! For twenty-five years success remained doubtful, success "by which since then gradually the privation, exertions, confidence and perseverance "of past years have at length been so wonderfully rewarded. May this example "encourage others who are in distress . . ."

A change for the better came when the age of railways began to dawn. And a happy invention in the domain of the peaceful industries, the manufacture of weldless railway tyres, put Alfred Krupp into the possession of the means required to carry out the long and wearisome experiments aiming at the application of cast steel to the manufacture of guns. The works then developed into a gun factory, and in rapid expansion acquired their great importance for the arming of nations, and therefore also for the prestige, greatness and power of Germany. It is a noteworthy coincidence, that the origin of the Krupp works and the birth of Alfred Krupp occur in an epoch, that, after years of the deepest humiliation, laid for the German nation the foundations of its resuscitation, and in which the germs of its revival to greatness took root; and again that the first budding prosperity of the works at the beginning of the 'fifties came immediately after those turbulent times, during which the hearts of the German people were imbued with the longing for and the firm hope in one united country, and during which the ground was prepared upon which, when the hour sounded, men of action could perform the work of union. The Krupp works had anticipated this political evolution, they had long become a great industrial power when, amid the thunder of Krupp guns, the German Empire was welded together. This leadership must be well borne in mind, when the significance of the Krupp works is to be justly appreciated for the venturing forth of German industry beyond its former limits, out into the market of the world, for the share which German industry now holds in universal commerce. It was the firm of Krupp above all others, that long before Germany had risen to the rank of a great political power, had all over the world, as far as industry goes, brought to honour Germany's name, and had thus become the pioneer of the victorious career of German industry in all parts of the world. Also in questions of social welfare, of institutions for the benefit of those belonging to the works, the firm of Krupp, at an early stage of its existence, entered on fresh paths, that have set an example to others, acting on the beautiful words of Alfred Krupp: —"The end and aim of labour is the good of all." Just to mention one thing only among others:—A sick-aid and pension fund, which was to provide aid in case of sickness, accident, invalidity, old age or death, had already been founded at the Cast Steel Works early in the 'fifties, and had been endowed with considerable subventions by the firm. And when in later years German legislation in favour of the working classes was taken up, it was Prince Bismarck himself who acknowledged and proclaimed that the Krupp institutions, which had given proof of their excellence, would serve him as a model in the creation of similar institutions, and that their statutes should be followed in the preparation of the legislative work that was being carried on. Down to the present day, the promotion both of the bodily and mental welfare of those belonging to the works, has been considered by the proprietors of the works as one of their chief and foremost duties. When Friedrich Alfred Krupp—born 1854, deceased 1902—died an early death, he left his works firmly established in technical and financial respects as well as in matters of organisation; works, that his clever mind, his capable and noble spirit had extended far beyond the limits they had when he took them over from his father, and which he had led out on to new roads.

To-day, at the outset of a second century of their existence, the works are in the hands of the fourth generation, who are willing to carry on these great works true to the traditions of their forefathers, in their spirit and in accordance with the ever growing requirements both of the present and the future. Even in these days the task that is set to the Krupp works is of the greatest significance for the German country. In the future as in the past, the duties incumbent upon the works, its proprietors and directors, require, alongside of loyal and diligent handicraft, the highest intellectual and moral forces. Duty and ambition combined must, even in the future, aim at the Highest and Best that manufacture can produce. The prosperity of the works rests fundamentally on the high character and capacity of the German nation. As long as this foundation is preserved, both in the masses of their workers and in the qualities of their leaders, the Works, the creation of the three Krupps will emerge victorious out of future storms, which will not fail to come as they came in the past. In 1871 Alfred Krupp wrote to the managing body of his works:—

> "The Cast Steel Works which have sprung up from an insignificant grain of seed,
> "in which originally nobody had any confidence, is now comparable in health and
> "vigour to an oak of fifty years' growth; like this oak, the works are capable and are
> "called upon to develop ever more powerfully for centuries to come. The works stand
> "in good soil, see that you protect the roots!"

May these prophetic words become truth! may this second century of their existence that is now opening, bring to the Krupp works prosperity and success, for the good of all that belong to them, for the honour and benefit of the German country.

# FRIEDRICH KRUPP.

## A CENTURY AGO.

When Friedrich Krupp resolved to found his cast steel works, he ventured on a matter which, at the beginning of the nineteenth century, occupied many a mind on the European continent, but which nowhere had found a practical solution. The problem of making cast steel lay, as it were, in the air, in Germany, after Napoleon's policy, for the whole of the continent, had established the motto:—"Enmity to England." For many years, experiments had been tried to make steel after the English process, but one establishment only, that of the Brothers Poncelet in Liège, had succeeded, in giving to their efforts some practical significance shortly before Krupp began his experiments. As for the rest, the manufacture of cast steel in an industrial way was still, as it had been for decades past, the strict and well guarded secret of England.

Favoured by its great wealth in mineral ore and coal, by its superiority in technical matters, aided by unlimited financial means, English iron industry had in the course of the eighteenth century run a long way ahead of that of the continent, an advantage which it tried to maintain by all the means it had in the way of constant technical progress and a clear-sighted determined commercial policy. The processes of smelting, refining, and forging iron had for centuries been restricted to the use of charcoal as fuel, and to water as the driving force of the bellows and hammers. Industry therefore had remained limited to small shops, widely scattered. It was England that first succeeded in substituting coke for charcoal in the blast furnace process; not only was charcoal getting ever more expensive, but also the hardness of coke made it possible to work furnaces of far greater capacity. Through the low price of coke, English pig iron manufacture was placed on an entirely new footing. Of equal importance for the development of iron industry was the invention of the steam engine, which made it independent of local restrictions caused by the need of water power. The consequence was a concentration of production in the localities most favourable to it, and an unrestrained expansion of the establishments, if only sufficient capital was at hand. On these foundations, manufacture on a large scale first developed in England, and the production of iron passed out of the hands of the small shop into those of large industrial enterprises. Only the process of refining on the open hearth, that is the reduction of pig iron into malleable iron, remained for some decades more restricted to the use of charcoal, as mineral coal spoiled the iron through the sulphur it contained. But when in 1785 the puddling process was invented in England, that is the process of refining in the reverberatory furnace, so that the iron no longer came in contact with the coal but only with the gases, refining also could use mineral coal took instead of charcoal, and the English iron industry also rose to the first rank in the production of malleable iron on a large scale.

The manufacture of steel also had made considerable progress in England. So far, steel, like malleable iron, had either been obtained through the refining process direct from the ore, or on the open hearth, from pig iron. The produce was natural raw steel. Since 1700 a steel of good quality had been produced from malleable iron by a subsequent process of carburisation or cementation, the steel so obtained was called cemented or blister steel. But all these kinds of steel, obtained in a solid or pasty, not in a liquid condition, were still of a certain inequality and impurity, which could not be got rid of, even by repeated refining or welding, and which proved a great disadvantage when the steel was used for delicate tools, engravers' chisels, watch springs, &c. The only steel, which was supposed to be free from these defects, was the famous Indian Wootz steel, which had been produced for centuries in the neighbourhood of Bangalore in Mysore. It was obtained in a wind furnace by remelting iron, obtained directly from the ore, in very small crucibles. This process, however, was then unknown in Europe and ironmasters commonly believed that steel was infusible. It was not till 1740, that a man, who was an amateur in the art of making steel, the watchmaker Huntsman in Sheffield, struck upon the idea of purifying steel of its residue of slag by remelting it, as the impurities rendered it particularly unfit for watch springs. After many failures he at length succeeded, by the process of remelting in small crucibles, in producing a very pure and uniform homogeneous steel, later called crucible steel or cast steel. Cast steel, therefore, originally was invented in answer to a demand of comparatively small extent, but it soon proved its superiority to all known species of steel, for numerous objects, especially for files and delicate cutting tools, so that it soon acquired a considerable reputation. Wrapped in the veil of mystery, which chiefly was supposed to consist in the application of a particular flux, and promising, as it did, large profits on account of its then still very high price, cast steel did not fail to arouse the emulation of inventors on the continent. The desire was fostered by governments holding out premiums, and as zealously as during the times of alchemistical studies the gold producing projecting powder was sought for, that flux, that refining medium of steel was hunted after, at the end of the eighteenth century and the beginning on the nineteenth.

France, following a trade policy hostile to England, an antagonism which for some time past had found its expression in a system of excessive protection, and whose government supported all endeavours that seemed likely to render the national industry independent of foreign countries, also led the way in this matter. The most noteworthy among other experiments were those of Clouet and Chalut, which had been carried on since 1788. These men tried to dispense with the process of cementation either through decarburetting pig iron or by carburetting soft iron in the crucible. These experiments, however, had no practical result. Not till the beginning of the new century do we hear of more successful experiments carried out by chemists and metallurgists on the continent. In imitation of the English process they used for the charge of their crucibles cemented steel which certain fluxes. In the way of laboratory work they at least seem to have obtained some small success, but few of them arrived at any practical and profitable application of their experiments, however modest. At Schaffhausen, a senator by the name of Fischer, at Bern the Gruber steel works were busy in making attempts to manufacture cast steel, at Liège, the Brothers Poncelet, the only ones who developed their process to anything like a business scale. German ironmasters had also taken up the problem. A certain Tieman, an employee of the Karlshütte near Einbeck had, already in 1804, tried a melting process, a report of which, drawn up by the Minister of Finance von Bülow, had been addressed to King Jérôme of Westphalia in September 1810. Also in Krupp's own neighbourhood experiments were being carried on about this time; for instance, by Schmolder, director of the Friedrich-Wilhelms-Hütte in the county of Lingen, but particularly in Wald near Solingen, where a flourishing industry in arms and tools had long existed, and where the cast steel problem therefore met with special interest. The firm Andreas Köller & Co. had even been granted a patent for a cast steel supposed to be equal in all respects to the English, but which has never been manufactured in a business way. Again, in the year 1808, twelve residents of the town of Wald, all practical men, had joined in a Chemical

Company, with a view to carrying out experiments in the laboratory of the apothecary Thomas, for the object of making English cast steel. Like most inventors of cast steel of those times, they worked after a recipe they chanced to find in some handbook of chemistry. In November 1811 they founded the "Walder Gussstahlerfindungsgesellschaft" and soon after, and at considerable expense, erected some works in the spot "in der Bech", in the parish of Merscheid. They obtained satisfactory results in a small way, but when applied on a large scale, the manufacture met with unexpected difficulties. The steel was neither homogeneous nor cheap enough to compete with the English and Belgian steel, so the Company of Wald did not succeed in finding a market for their produce. After a languid existence of several years the company was finally dissolved in 1823. Other enterprises met with a similar fate. It must not be forgotten besides that the demand for cast steel on the continent was then hardly sufficiently important to support an extensive manufacture. It was a costly stuff, indispensable for certain purposes, but by no means an article required for use in large quantities. In France cast-steel tools were in demand for the working of precious metals, in Switzerland, tools and springs for the watch making industry, in Germany, especially in the county of Berg, there was a certain demand for cast-steel engravers' and coining dies, for cutlery and other subtile tools; and in all countries for cast-steel files. It was only some years later that cast steel became of importance in the mints, where coining methods were being improved about that time.

There was one particular circumstance that caused the demand for cast steel on the continent, during the epoch from 1806 to 1812, to be rather lively, more lively even than would have answered the real want:—yet even the quantatively smallest need can turn into a real distress, if it cannot be satisfied. Such was the case here. The war against England's trade, which Napoleon had resumed since 1803, had arrived at its climax in the years 1810 and 1812, and had barred one after the other of the continental frontiers against English importation. The increase of import duties of the first years was succeeded in 1806 by Napoleon's fatal decree which declared the blockade of the British Isles and prohibited all trade and commerce with them. By the Peace of Tilsit, in 1807, Prussia and Russia had to join this continental blockade, Denmark, Spain and Austria followed. It must indeed be admitted that it was utterly impossible to enforce the blockade strictly. By force and smuggling English produce were ever finding new inlets into the continent, and a very flourishing commissioners' trade sprung up, whose chief seat was Holland. Through the incorporation of Holland in the year 1810, which was soon followed by that of the German North-Sea coast, the western continent became more effectually closed against English importation. The consequence was a displacement of the inlets of importation towards the east, and a rise of commerce and industry in the eastern parts of Germany and in Austria. Napoleon's answer was the decree of Trianon, which also closed France on the East, and a brutal destruction of all manufactured and colonial goods, that could be proved, or even were only suspected of being of English origin, in the German commercial towns, and especially in the states of the Confederation of the Rhine. Under such circumstances naturally both the demand for and the price of English imported goods went up to an excessive height, and cast steel was among such products. But this state of things was neither natural nor lasting. Its duration merely depended on the predominance of Napoleon's power which, after a short career met with a sudden end, and again ceded the place to the sway of England's world-wide trade. And as regards the state of the market it was through Napoleon's reckless proceeding that, instead of the prosperity which he had expected and hoped for economically, all countries had become entirely exhausted, the purchasing power ran low, commerce and trade became extinct, wherever he had put his foot as a ruler. He did not render Europe independent of England, he only contributed to impoverish the continent by depriving of the raw material those trades that depended on importation, and from those that worked for exportation he took away their market.

This effect of the continental blockade was the more keenly felt in the German states, the nearer they were to the French frontier. They were of more fatal consequence to the Grand Duchy of Berg, which had been created by Napoleon in 1806, and with which had also been incorporated the Princely Chapter and the town of Essen, after they had been for a few years under Prussian dominion. In spite of the hitherto prevailing division into a multitude of small states, and in spite of the disfavour of a trade policy governed by dissension, a flourishing industry had developed above all in these parts of the country. Its produce, chiefly iron, steel and textile goods had found a market even beyond the sea, but the chief country into which the export went was France. The coal of the Ruhr district was sold not only in the country itself, but also in France and in Holland, particularly since transport had been facilitated by making the Ruhr navigable. The export and transit trade was favoured by the geographical situation of the Rheno-Westphalian district of industry, lying as it did between important commercial roads leading from north to south. For long years therefore, this trade has been an important source of income to its population. The annexation of the Grand Duchy of Berg, and the friendship of France therefore, were at first warmly welcomed, for being embodied into a larger community of states, there seemed to be a possibility for a better utilisation of the natural resources of the country, and of obtaining a wider market for the produce of their trade. Instead of this, however, there came one blow after the other, first, the prohibition of importation, then the barrier of the frontiers, lastly the closing of France and Holland against the states of the Rhenish Confederation. All requests and applications clamouring for an alleviation of these most oppressive economic conditions in the Grand Duchy of Berg proved vain. What use, thus the citiziens of the town of Werden asked in an address to their mayor, what use is the progress of the last twenty-five years, if the new masters do all they can to kill this industry, by depriving it of its market. "The barrier of the Rhine frontier was the beginning. Commerce has become a beautiful dream. At the same time both the Dutch frontier, and that of the Elbe have been closed, and exportation of goods produced on a large scale has thereby been rendered impossible. Manufacture itself also has been severely impeded through heavy duties on the importation of raw stuffs. The consequence is, that the whole export trade is going down. Only those branches of manufacture that have not to reckon with exportation, carry on a modest existence. All aspiration and idealism have been driven out by such a state of things." Under such conditions the people would have been satisfied to be incorporated into the Empire, and so share at least the fate of a bigger country, but they were even denied that. Also in small things, relating to their own local district, the hopes of the population of the counties of Berg and Mark, were not fulfilled. The making of roads, the most important foundation even for the most modest development of commerce and trade, was begun indeed, but never finished. The military impositions swallowed up all other needs. In the district of the Ruhr complaints could be heard that the horses of the coal carriers stuck in the morass; traffic by carriers' carts was not to be thought of. In 1810 the drapers called the road from Werden to Mülheim the worst in the whole Grand Duchy; the road from Essen to Werden, traced out since 1805, was not finished in 1825. Even navigation had to fight against enormous difficulties; not less than fifteen custom houses encumbered the navigation on the Ruhr, not counting the dangers caused by stones, shallows, weirs, &c., so that five per cent of all vessels perished before they reached the Rhine.

If in towns like Werden and Kettwig it was industry chiefly that suffered from these conditions, at Essen it was commerce that felt them. Essen, now the centre of the Rheno-Westphalian district of industry, was then a small country town of 4000 inhabitants, but a town which could look back on a very important past. The old Grand Chapter of Essen went back as far as the tenth century, and once had enjoyed the particular favour of the Saxon imperial dynasty. Since the Reformation, by lasting struggles, the town of Essen had acquired considerable liberties and privileges, so that its position differed little from that of an imperial free town. Besides agriculture, which formed the chief means of existence of its inhabitants, in the course of time a considerable import and transit trade especially in colonial goods had developed. And the first families of the town, among these the Krupps, had been engaged in it at an early date. Nor were industrial establishments and enterprises altogether wanting, there was a gun factory, the last remnant of a once very considerable Essen industry in hand fire-arms. And in 1807 the wellknown mechanic Franz Dinnendahl, the builder of the first steam engine in the Rheno-Westphalian district, had transferred his establishment to Essen. In the immediate vicinity, along the Ruhr and its side valleys, coal mining had been carried on of old; governmental regulations had, since the second half of the eighteenth century, very considerably promoted it in the Prussian districts, and also the Grand-Ducal government adopted the Prussian mining regulations. The steam engine gave a new impulse to mining, and even the continental blockade had at first a favourable effect, since by excluding English coal from the continent, it facilitated the export of coal from the Ruhr into Holland. During the French rule, coal mining, and the sale of coal, formed with agriculture, almost the only means of subsistence of the Essen population. Since limonite or marsh-ore was found in a small way, small iron works had been erected to the north-west of Essen during the second part of the eighteenth century. Three territories, that of Prussia, of the Electorate of Cologne and of Essen, met at this spot. And since each government was bent on not letting the wealth of the soil go abroad, but rather on having it turned to profit in the country, each of them very soon erected their own iron works, the Electorate of Cologne owned the St. Antoni-Hütte, Prussia the Gutehoffnungshütte, which for a number of years became the property of the family of Krupp, and the works Neu-Essen were under the sway of the Prince Abess.

Such were the political and economic conditions of Rhineland, when the first attempt was made to transfer the manufacture of cast steel to German soil. Such in particular was the state of things in the immediate neighbourhood of Essen, when an energetic and highly gifted descendant of an old and greatly respected Essen family, of a race of patricians, the Krupps, was the first of his name to step into this field. It was by a strange coincidence of inward and outward circumstances, of motives springing from his character and his surroundings, that Friedrich Krupp was pushed out of the beaten and safe path that his forefathers had trodden, and was driven on to entirely new roads, undertaking, as he did, an enterprise in which many had failed and a few only succeeded, which was begun in uncertain times, and promised a modest gain, even if it turned out for the best—modest, considering the still very limited market for cast steel,—if for the worst, it meant the loss of his whole paternal fortune.

For centuries the Krupps had belonged to the distinguished senator families of their native town, and had taken part in its administration in the capacity of burgomasters and syndics. In the sixteenth and seventeenth centuries many of them besides had gone in for commerce, and it had been a commercial man who had laid the foundation of the fortune the family enjoyed, at the time when Friedrich was born; this was his grandfather Friedrich Jodocus Krupp. He started a business in colonial goods and grocery with a capital of 615 Reichstalers, in the year 1732. This enterprise flourished, and Friedrich Jodocus Krupp invested his gains chiefly in land, thus adding to the property he had inherited from his father, who died in 1734. After the death of his first wife Friedrich Jodocus married a second wife, Helene Amalie Ascherfeld, a lady descended from an old Essen family whose members had been merchants and senators. She was hardly twenty years old, when she wedded the forty-five years old childless widower. In 1753 the long wished-for son was born. He was christened Peter Friedrich Wilhelm; a second son followed in 1755, and in 1757 the father died leaving to his young widow the care of their children, their business, and their fortune, which already then was not inconsiderable. This woman went about the task that had fallen upon her with extraordinary energy. She kept the management of the business in her own hands until her old age, and under her administration it grew rapidly in extent. In addition to the old customary goods new ones were taken up, such as cloth, linen, and porcelain. English business relations were added to those already existing with Dutch firms. The lively and stirring spirit of Amalie Krupp seems to have urged her also to take a part in the manufacture of goods. She started with small beginnings, and in the year 1759 had a mill erected for the making of snuff. More important became the manufacture of cloth and linen and the dyeing of stuffs, carried out by home industry. In her old age, she manifested a certain inclination for industrial enterprise, a bent which had been alien to the former generations of the Krupps; she invested a part of her fortune in mining shares. When in 1797 the old "Walkmühle" or "Halbachsmühle" near Essen, formerly owned by the City Wool Office at Essen, and then, passing through several hands, had also been employed for other industrial purposes, was again for sale, Frau Krupp-Ascherfeld bought the property, and after having first let it, she gave it to her younger grandchild Wilhelm. On the site of this mill, which was an hour distant from the gates of Essen, the first building of the Cast Steel Works was erected in later years. One of the strongest exhibitions of Frau Krupp-Ascherfeld's energetical disposition, was the purchase of one of the iron works mentioned above, the Gutehoffnungshütte at Sterkrade, when she had already arrived at an advanced age. In the 'eighties she had aided the builder of the works Eberhard Pfandhöfer, by advancing him considerable sums of money. For some time her son Peter had a share in the works to the value of one fourth. When owing to the untoward conditions of the times Pfandhöfer could no longer keep up the works, they devolved upon the widow Krupp-Ascherfeld, in 1800, she being the chief creditor. Part of the works consisted of an iron foundry, which according to a price list of the year 1806, issued by "the widow Krupp of Essen on the Ruhr" manufactured "all sorts of cast-iron goods". The new proprietress also took up this line of business most energetically, a number of technical improvements were made in which her grandson, the young Friedrich Krupp, also took a part. It is worthy of notice, that the period of ownership of the works by the Krupps coincided with the beginning of steam-engine building, a branch of engineering for which even at the present day the Gutehoffnungshütte is highly reputed. The mechanic Franz Dinnendahl mentioned above, who in those days enjoyed a certain reputation as a designer of steam engines, entertained friendly relations with the Krupps, and had received monetary aid from the widow Krupp-Ascherfeld in the erection of his works at Essen. For more than fifty years, this woman, who in an unusual way combined cleverness with energy and strength of will, exerted a determining influence on the development of the Krupp family. In her nature are to be found to a great extent those germs that later on developed in the character of her great-grandson Alfred into high-spirited energy and industrial skill. Her son, Peter Friedrich Wilhelm, whom she outlived by fifteen years—a younger son had died very early—played a poor part in business matters beside her. He was chiefly engaged in administering the family fortune, and besides took a part in public affairs. In 1778 he had become a member of the college of patricians, of which he became president in 1785; he was also an officer of the civic militia, who took charge of the public watch and order. In 1779 Peter Krupp married Petronella Forsthoff, whose inheritance again considerably increased the family property. The continuance of the Krupp family then depended on very few members, the birth therefore of a son and representative of the family was hailed with joy. He was born on the 17th of July 1787, when already a rich heritage of social regard and personal wealth was laid into his cradle. This boy was Friedrich Krupp, the founder of the Cast Steel Works. His birth had been preceded in 1782 by that of a sister named Helene, who in 1803 wedded the Prussian lieutenant Johann Christian Friedrich von Müller; she together with her husband faithfully assisted their brother, in the great sorrows and worries of his later days. A younger son, born 1791, was christened Wilhelm. In this domestic circle, the life of Peter Krupp's wife, whom he left a widow after sixteen years of matrimony, also ran along smooth paths. She had little chance, especially after the early death of her husband, of asserting herself by personal actions by the side of her energetic mother-in-law. Her existence was entirely filled up by the education of her children to whom she was always a devoted and self-denying mother.

Hardly anything is on record relating to Friedrich Krupp's childhood and youth. Only his later development reflects the influence that had worked upon him when a boy, and in which had a part the ever active grandmother, the father ever conscious of his dignity as a patrician, and the mother who clung with particular devotion to her eldest son. Friedrich was eight years old, when his father died. It is more than probable, that of the two women, the energetic grandmother had the greater share in guiding his education. She being the mistress of the family fortune, also set the goal for the child's future, this goal was the commercial profession. From his early youth the boy seems to have been put to office work. In rough copies of letters of the year 1800, his hand-writing may be recognised; this may have been the beginning of his apprenticeship. After this period he held a post at Camen in Westphalia, till 1805; then his grandmother sent him to the Gutehoffnungshütte, of which she had become the proprietress some years before. By doing so she gave a new turn to the bent of the youth, who was of a lively disposition, and in a certain sense seemed to be something of a genius. Friedrich Krupp did not limit himself to the commercial side of the works, but also took a share in the technical department, with an interest that rapidly grew, in which work the foreman Linnhoff, who since 1800 managed the technical branch of the works, became his teacher. It so happened that in those very years the works were engaged in new and difficult problems. Since 1806 the Gutehoffnungshütte had received orders from Dinnendahl to cast parts for his "fire engines". The first order was for a 40-inch pumping engine, and a 15-inch engine for coal extraction. Both were destined for the coalmine Sälzer & Neuack which is now in the possession of the Krupps. The works were not yet equipped for the casting of such pieces. The big cylinder therefore had to be recast five times, and eventually in three separate pieces, so that the engine could only be set to work in 1809. This kind of occupation suited the inclination and disposition of Friedrich Krupp much better than the to him somewhat insipid calling of a commercial man. Here the future stood out before him in an alluring form, for which just then, after the formation of the Grand-Duchy of Berg and the suppression of English importation, favourable prospects seemed to open. The grandmother also seems to have given way to his wishes, she approved of his becoming engaged to be married, in 1806, to Therese Wilhelmi, the daughter of a notable Essen merchant, although the young lady was only sixteen, and the young man only nineteen. She also conferred upon him as his property the works for a moderate sum, on the 1st of May 1807. His possession, however was of short duration. The times changed quickly, and instead of the hoped-for rise of industry, very soon the first signs of a decline came. With a quick and justified decision, the widow Krupp-Ascherfeld cancelled the grant, and resumed the works in order to dispose of them by sale on the first favourable offer. Such a sale was indeed within the reach of probability, since the old territorial impediments no longer existed, and wishes for the fusion of the several works had been manifested. Friedrich Krupp still remained for a short time at the works as director, and his wedding on the 10th of August 1808 took place there. Soon after, however, a comparatively high offer of purchase was made, and in the November of that year the Gutehoffnungshütte passed as common property into the hands of Heinrich Huyssen of Essen, Franz and Gerhard Haniel of Ruhrort, and Gottlob Jacobi of the works at Neu-Essen for the price of 37800 Reichstalers. Through the union of the Antonihütte and the Neu-Essen works with the Gutehoffnungshütte in 1810 was created the concern Jacobi, Haniel & Huyssen, which developed into the "Gutehoffnungshütte, Aktienverein für Bergbau und Hüttenbetrieb", of to-day.

Most likely the young couple left the Gutehoffnungshütte with some feeling of regret. Friedrich Krupp was a man of distinct self-dependence and full of enterprise. His later life proved that his stay at the iron works had indelibly influenced his inclinations and his hopes for the future. From a sphere of action comparatively wide and rich in prospects, he had now to return to the narrow conditions of the good old town of Essen. He took up his residence in his grandmother's house, on the Flachsmarkt, in the same house where on the 26th of April 1812 his eldest boy was born, the boy destined to complete his works and his hopes. On his return to Essen, Friedrich Krupp again took up the commercial profession, and with the financial aid of the widow Krupp-Ascherfeld, he founded a business for the importation of colonial goods, in which his younger brother Wilhelm was for a short time his partner. Such an enterprise seemed in those times, and through the situation that had been created by the continental blockade, to promise large profits. The transactions of course were also attended by great risks. The ever changing political conditions demanded from him who conducted the business, great readiness in making his dispositions, he had to watch closely now in one country, now in another, and from one day to another, the constant change of market prices, the constant displacement of the possibilities for the roads of inlet and transit. In these business matters and transactions Friedrich Krupp in spite of his youth developed a certain large conception, and an agility of mind which was well suited to the circumstances. After the death of his aged grandmother, in May 1810, her business also, which, as it had always done, went in chiefly still for retail sale, was taken over by him, and amalgamated with his own enterprise as the firm of Friedrich Krupp. The importation business at first was very successful, but soon the political state of things became less favourable. The closing of the frontiers became more severe, the harsh measures against all imported goods hunted after by the officials became insupportable. Heavy losses occurred, and finally compelled Friedrich Krupp to give up a vocation, which he had assumed less from personal inclination, than under the pressure of tradition and the influence of his grandmother. His resolution to give up his trade in colonial goods entirely, had become fixed in April 1812. But before taking this step he had with a quick resolve entered upon a new enterprise which was to claim his interest more than all previous ones, and which henceforth was entirely to fill his life:—the founding of the Cast Steel Works.

## SMALL BEGINNINGS.

Considering Friedrich Krupp's nature and circumstances, the idea of his trying his hand at the experiment of making cast steel, then so much in vogue, could not be alien to him. The story, however, that he had already been engaged in such experiments at the Gutehoffnungshütte in common with Jacobi, the manager of the iron works Neu-Essen must be treated as a legend. Jacobi, the son of the founder of the Sayner Hütte, possessed, no doubt, considerable metallurgical knowledge for his time, but there is no trustworthy record of his having been occupied with the cast steel problem. Krupp certainly had preserved from that epoch of his life an interest in and a comprehension of metallurgical work. The zeal with which, after the experiments for making cast steel had been started, he immediately applied himself to the manufacture of refractory crucibles, and the ability with which he acquitted himself of that difficult part of the business, proved at the very outset that he grasped its importance for the problem in view, and at once dealt with it intelligently. The whole cast steel problem, as has already been intimated, was so to speak in the air. The experiments carried out at Wald were no doubt widely discussed, the scientific reviews gave accounts of prescriptions for the manufacture of cast steel, and Krupp who was much interested in inventions, and who was a fairly well-read man, most likely received many an incentive through this channel. At a later period he wrote himself in the "Wissenschafts-Blatt" published at Hamm, and issued as a supplement to the paper "Rheinisch-Westfälischer Anzeiger", that he was one of those "entrepreneurs" who had proceeded according to what had been publicly written on cast steel making, but who had not become initiated into the art by experiments on a small scale, and therefore had only to regret them. As manager of an importation business, he probably, by his own experience, well knew the demand for English cast steel, and the difficulties attending its supply. Among his nearer relations and acquaintances, there were a number of merchants dealing in iron and steel goods. Krupp's father-in-law Wilhelmi was in fact his first buyer, when in 1815, after three years' experiments, he succeeded in producing small lots of cast steel of faultless quality. Friedrich Krupp did not lack the selfconfidence needed to solve problems to which he had earnestly set himself. The idea therefore of founding Cast Steel Works, which certainly was very alluring, had probably long haunted his mind. But it was only after the death of his grandmother that he came into the possession and the free disposal of a considerable fortune. This money procured him the means of embarking on so venturesome an enterprise as the foundation of cast steel works. Together with his own fortune and the dower of his wife, his wealth towards the end of the year 1811 amounted to the, for those times, very respectable sum of about 50,000 Reichstalers, in what was called common currency, a Reichstaler being about 4/5 Taler Prussian currency (all figures subsequently given as regards sale, production, &c. are for the most part in the latter currency.) A small portion indeed only of this fortune was in liquid funds. Most of it consisted of immovable property, part only alienable later on, part altogether unalienable in the interest of the children, part still involved in the business hitherto carried on, the liquidation of which was not terminated until far into the year 1818. The consequence was that these sums only very gradually became available for Krupp's new enterprise, and that he himself for years to come remained hampered by this liquidation business. This circumstance also explains why Friedrich Krupp, in spite of his own rather considerable means, had, shortly after the foundation of the Cast Steel Works, to resort to the financial aid of his relations, which support was willingly granted during the first years.

Regarding the prospects of the new enterprise, the general interest prevailing throughout the industrial districts of the counties of Berg and Mark in a national cast steel manufacture, enhanced as it was by the exclusion of English cast steel from the continental market, certainly spoke favourably for it. Krupp's own resolution was backed up by his personal bent for technical things, and his undeniable gift for metallurgical research. Also in respect to the locality chosen, he was entitled to believe himself favoured by circumstances. The raw materials he needed for cast steel making were conveniently at hand, there were a number of coalmines in the vicinity of Essen and, although it was poor in ore, the ironworks of the district of Berg were not too far off. Considering the distressing conditions of the times, there was no want of labour, skilled workmen could easily be had in a neighbourhood with an industrial population. Essen, therefore, in respect of its situation, and of its surroundings could well be looked upon as a place suitable for the new enterprise. On the other hand unfavourable circumstances were not wanting either, and a more timid nature might easily have wavered in the face of them. The war with England and the French protective policy still weighed heavily on trade and industry, and paralysed them. And who could know what the immediate future might bring? Napoleon so it seemed, was on the summit of his power, but his omnipotent position had so far evidently been of little avail to his allies, and again dark clouds were rising on the political horizon. Friedrich Krupp, however, a man of sanguine nature, was not likely to be deterred from his project. In his opinion the time for action had come, and when towards the end of the year 1811 he happened to come across two men, who according to their assurances, possessed that knowledge which he personally lacked, he at once and unhesitatingly proceeded to carry his plans into practice.

These men, whose appearence at Essen most likely gave Krupp the final impulse to form his long cherished wishes into a resolution, were the two brothers Georg Carl Gottfried and Wilhelm Georg Ludwig von Kechel, former Nassovian officers, both advanced in age and natives of the town of Anspach. They called themselves steel makers, and perhaps by dint of reading and experimenting on a small scale, they had gained a certain, although quite insufficient knowledge of the manufacture of cast steel. At any rate, they contrived to convince Friedrich Krupp, that they had the knowledge of the long searched for flux upon which, according to the general belief then, the making of cast steel depended, and on the 20th of November 1811 a deed of partnership was signed between the two parties, for the purpose of establishing Cast Steel Works bearing the firm of Friedrich Krupp at Essen. The three partners agreed:—"to establish here at Essen works to be carried on in common, for the manufacture of English cast steel, and of all products resulting therefrom." Krupp advanced the necessary capital in instalments, for which interest was to be paid him at the rate of 4 per cent, and for which he received a mortgage on the works to begin with. Until these advances were repaid, the establishment remained his property, so that the partnership only referred to the profits. The two von Kechels undertook to instruct Krupp in the technique of cast steel manufacture, and further "as long as free trade with England was not restored, or until other works of a like nature became abundant in Germany, to secure a least 40 to 50 per cent clear profit on the cast steel produced, every time the capital so far invested was turned over." Krupp looked after the commercial part of the business, and reserved to himself the right of signing in the name of the partnership, whereas the trade mark was to be chosen by the partners in common. Until the establishment turned out adequate profits, the two von Kechels were each to receive, at the beginning of every month, the sum of 21 Reichstalers out of the business funds. The partnership was arranged for 20 years, before the lapse of which none of the partners could dissolve the partnership or transfer his share to any other person; only, in case "the working of the establishment should be connected with manifest loss", each of the partners should be free to abandon the engagement. Soon after the establishment had started work, Krupp, on the 9th of April 1813 substituted a second arrangement, by which the first was cancelled; because he had in the meantime arrived at essentially different notions of the knowledge of the two brothers von Kechel; this second agreement made him the sole proprietor of the steel works. The Kechels thus instead of partners which they had been, became employees of the firm for lifetime, they no longer had any claim on the establishment or on any profits that might result. They continued to live at the Walkmühle rent free and with the enjoyment of some other emoluments.— Soon after the first agreement had been signed, the experiments in search of the best melting method were begun, in order not to let the time until the erection of the buildings go by unutilised. These preliminary experiments took place at Essen. In a shed still existing, which was an annex of the house number 17 of the IInd Weberstrasse, a cementing furnace and two small smelting furnaces for one crucible each, were put up, the necessary draught was obtained by a chimney 8 meters high. Bars of mild iron, principally of very pure Osemund iron, were bedded in charcoal powder, after which they were kept for about five days at red heat in the cementing furnace, and so were converted into blister steel. The latter was broken up into pieces, sorted according to the aspect of the fracture, and charged into Passau graphite crucibles with an addition of wood ashes, glass and such like substances, by way of flux. The fusion was done by means of coke, obtained from coal ridded of its sulphur by glowing it in piles. The casting was first done in sand moulds, such as were used in casting iron, the ingots obtained were hammered out on the anvil. The first casting took place in January 1812. Messrs. von Kechel went on experimenting in this way on a small scale for almost a year, without arriving at any sure method or producing uniform steel. It was the same rock on which nearly all former enterprises had been shattered. When the experimenters had really been successful in producing a tiny steel ingot in the small crucibles of the experimenting furnaces, they invariably failed to secure uniformity of the various charges, and when trying to put the results of their experiments into practice on a larger and profitable scale, their whole process generally came to grief.

While these experiments were carried on in the Weberstrasse, Friedrich Krupp, still firmly convinced of eventual success, had given his whole soul to the erection of the buildings for the works in which the business was to be carried on at once on a practical scale. The steel foundry and the forge were to be built at the Walkmühle, mentioned above, which was situated at about an hour's distance to the north of the town of Essen. Friedrich's grandmother had at one time bought this small property of about 1½ hectare; later on it had been inherited by Friedrich's brother Wilhelm, and it was from him that he had acquired it in December 1811, by giving him a mortgage on it. The water power of the Berne, which for centuries had driven the wheels of a fulling mill here, and later on of a boring mill, and also the wish to utilise this family property determined Friedrich Krupp to select this locality. It soon, however, became evident that he had not been fortunate in his selection. The small stream, long neglected, remained too poor in water to drive the wheels of the hammer continuously, in spite of expensive improvements made on it, and the laying out of two ponds. Lack of water in summer and occasional frosts in winter often caused an interruption of the work. The situation of the place was not favourable either. The distance of the Walkmühle from the town of Essen, where Krupp continued to reside, was a serious difficulty for the constant supervision of the building, the distance between the new works and the coalmine, the coal of which had proved the best for his purpose, was greater still. The condition of the roads leading to the works, was so bad, that great difficulties arose in carrying the iron and coal supply there, why, at times, the supplies had even to be carried on horseback. During the wet season whole cartloads of juniper fagots had to be sunk into the morass of the "Eselsweg" and the "Hammerstrasse" which formed the nearest ways from the town to the Walkmühle.—Krupp had the new buildings erected spacious and solid. The main building had two stories; besides the foundry it contained a crucible shop, a room for the raw materials and a store room. In the foundry, a cementing and a crucible furnace were put up, the building stones for which had come from a sandstone-quarry, which Krupp had bought at the village of Rellinghausen. The building for the hammer was placed between two water branches, and contained in its massively built basement a tilt hammer to forge the ingots, a crushing mill to pound the raw materials for the crucibles, also a forge and anvil. The hammer and pounding mill were driven by means of a large shaft through the overshot waterwheel. A second undershot wheel most likely was destined to work the bellows. Even to this day such old tilt-hammer shops may be found here and there in the valleys of the Lenne and Volme. The upper stories of both houses were arranged for workmen's dwellings, for the smith, the crucible makers, and the founders. The old dwelling house of the Walkmühle contained lodgings for the two von Kechels and Mr. Tacke, who had the superintendence of the works. When towards the end of the year 1812 the buildings were finished, and equipped with the necessary plant, the preliminary experiments in the Weberstrasse were stopped, and all the materials moved to the Walkmühle. Krupp at once started the manufacture of cementing steel on a large scale, and in May 1813 trials were begun in making cast steel in crucibles of a larger size. The melting of steel in those days, also in English works, was done in furnaces that got their draught by means of a high chimney; the fuel used was coke, which was piled up round about the crucibles, and out of which the crucibles, which then, by the way, were only 20 to 25 centimeters high, had to be carefully taken, after the melting process was over. Krupp's first furnaces very likely bore most resemblance to the glass melting furnaces then in use. A certain Mr. Mustoph, manager of the glass works at Königsteele near Essen, and who at that time was in close relations with Krupp, also gave his advice in the building of the furnaces and the manufacture of the crucibles. These were the most important factors in the making of cast steel, of far greater importance than the mysterious flux, which all inventors of cast steel, such as the brothers von Kechel, added to their charge; Friedrich Krupp also very soon became convinced of this fact. The crucibles most approved of in those days were the graphite ones of Ips and Passau. They not only possessed high refractory properties, but also best withstood the excessive changes of temperature. Already during the preliminary experiments, Krupp had devoted himself to the manufacture of crucibles with particular zeal, and with the aid of Mustoph succeeded in making crucibles of clay and black lead or graphite which possessed even more resistance to fire than those of Passau. Krupp pressed his crucibles in copper moulds. He took his coal supply from the mine Sälzer & Neuack, and in particular from the seam called Röttgersbank, since this quality proved the best for his use; he coked this coal in piles at the Walkmühle. The iron supply was taken from various works in the county of Mark. For the sake of economy Krupp sometimes took iron scrap which was cheaper, from the sheet-rolling mill at Spillenburg. The melting of the cast steel was personally attended to by the brothers von Kechel, Krupp took a share in it with much interest and rapidly growing knowledge, whenever his time permitted.

The greater, however, his own understanding of things became, the more clearly he saw the incapacity of his partners to fulfil their obligations; they incessently tried now this, now that, without obtaining any lasting success, and after the melting process had been taken up at the Walkmühle on a business-like scale their produce became completely useless. They attributed the failure to the fact, that larger crucibles were now used, but Krupp evidently could not stop short at the manufacture of the small portions of the commencement. If cast steel were to make its way in the measure proposed, it must be possible to carry out its manufacture on a regular working scale, and in appropriate quantities, if not, all hopes built on the enterprise were ruined. The terms of the engagement between the partners spoke of cast steel and of "all produce resulting therefrom" which meant in the first place, wire, tools and cast-steel files, for which there was a great demand not only in the counties of Berg and Mark, but also in Holland and France. Already in April 1812 a certain Heyder of Ronsdorf had approached Krupp with a proposal to erect a file manufactory on French territory on the left bank of the Rhine, from which the French and Dutch demand should be supplied. Krupp and his partners indeed at that time had the erection of such works in view, on the other side of the French frontier, in the town of Mörs. A clergyman of that place named Diergardt agreed to take the preparatory steps towards the new enterprise. The future manager of these works was to be Diergardt's son, afterwards Baron von Diergardt, a well known enterpreneur, and the founder of the firm of Diergardt at Viersen; he had passed his apprenticeship in Krupp's business. The establishment was about to start work, when towards the end of 1812 political changes intervened, and brought the whole business to a standstill, which endedin complete failure during the course of the following year. At Essen, on the contrary, the manufacture of files was begun in May 1813. In spite of all failures so far, Krupp had not abandoned the hope of reaching his goal with the aid of the von Kechels. A file smith and a number of file cutters, from the environs of Remscheid, where this industry was indigenous, were engaged. Since the manufacture of cast steel had not yet succeeded, Krupp had his cemented steel made into files, and when it proved unfit for this purpose, he had the files made of natural or raw steel which he ordered from some place in the county of Mark. He found a market for his files among the industrial population of the neighbourhood, and to a small extent even as far as Holland. Thus the first period of productive work took a shape entirely different, indeed, from what Krupp had expected, but which still left room for his hope to attain his aim some day. About nine men were kept at work in this way during the summer and autumn of the year 1813. While the brothers von

Kechel were going on in their fruitless attempts at producing cast steel, Friedrich Krupp's time was taken up partly by the extension of the buildings, but above all by his activity in the service of his native town, to which he had early devoted himself, and which engaged his time ever more as years went on. Soon after his return from the Gutehoffnungshütte, pursuant to the family traditions, he had taken upon himself civic duties. In 1812 he was nominated a "town councillor", in which function he had been confirmed even after Essen had reverted to Prussia, and he showed no less zeal in his municipal duties than he did in any other task he undertook.

It was perhaps by this preoccupation that Friedrich Krupp was prevented from recognising the utter incapability of his partners immediately after they had assumed their work, and from making use of his right, according to the letter of the agreement, to annul the partnership. The useless trials were thus protracted longer than was good for the state of Krupp's finances. During the autumn of 1813 the events of the war even caused work to be temporarily suspended, while Krupp himself was completely withdrawn from his own affairs by his office of alderman and commissioner for the billeting business. Besides, the burdens of war were doubled for him since he had to contribute to the imposts as a member both of the communities of Essen and of Altenessen, where his works were situated. Workmen were ordered away to Wesel to raise earthworks, orders were issued to furnish supplies for the troops, soldiers were quartered in the building of Krupp's works. It was only in 1814 that the steel-making experiments could be resumed. The file manufacture was also continued in a small way, but with little success, as its products could bear no comparison with the English cast-steel files.

Thus in this year already Friedrich Krupp's situation became very precarious, all his available means had been exhausted by the experiments and the building costs, to cover these and the working expenses he had already been obliged to ask considerable loans from his relatives. Further sums were denied to him, as the success hitherto attained had remained so very far behind their expectations. The political situation had also become less favourable to the enterprise. The liberation of Prussia from the French yoke, however joyfully Krupp's national sentiments had hailed this event, shook, nay even destroyed in a great measure the very foundations on which his enterprise reposed. The cessation of the continental blockade in March 1813 again gave English cast steel unhindered access to the market of the German states. Not only Krupp, but many another enterprise in Westphalia and in the countries about the lower Rhine that had been based upon the exclusion of English goods from the market, severely felt the blow dealt them by this event. The return of Essen to Prussia promised to be in a certain measure a compensation, but the purchasing power of the whole market still remained very feeble. Trade and industry being very low in the western provinces after the war, the demand for goods was far from what might have been desired. Krupp's business was still barred from the eastern part of the monarchy by the provincial custom duties raised in the old Prussian provinces. The scantiness and costliness of the means of conveyance in those days besides, added to the difficulties of opening up business relations with them. But worse than all these things, was the incapacity of the brothers von Kechel, who, after having resumed work, were not able to produce the least result. In November 1814 therefore Krupp, after much hesitation and vain expectation, finally resolved to part with them. He gave them notice to quit their position and residence, and announced to them that henceforth he intended to carry on his works and to try to improve them without their assistance. The brothers von Kechel, who still maintained that Krupp himself had "dug the grave" for the steel-making process by using his large crucibles, made an attempt to insist on the engagement, but Krupp remained firm in his resolution, and on the 12th of November they left the works and the service of Krupp. They returned to their former calling, enlisted as soldiers, and died as Dutch military pensioners about the middle of the 'thirties.

Krupp at first considered, whether he should carry on the works or abandon the project, in agreement with the wishes of his relatives, but his final resolve was in favour of the former plan. He ventured to continue, relying on the knowledge which he had acquired during the period of experiments. Not only in the making of crucibles, but also in the melting process, his experience had been considerably expanded, and, indeed, the next few months brought the first sale of cast steel, although it was in very small lots only. Things looked worse in respect to his financial position. During the three years of his partnership with the brothers von Kechel, Krupp had spent 15,000 Reichstalers for buildings and the equipment of the works, the working expenses amounted to 17,000 Reichstalers and only 1400 Reichstalers figured on the credit side of the balance sheet as receipts for goods sold. Beside his own capital he had already borrowed 20,000 Reichstalers from his brothers and sister, and it was only by the confidence in his own good cause, and his mother's assistance, that he preserved the courage to continue his works in spite of the most urgent advice to the contrary on the part of all his relatives. It was, indeed, henceforth in the first place Krupp's mother who, having become the universal heiress of her younger son Wilhelm, deceased in October 1815, continued to support Friedrich's enterprise, and who stood faithfully by him in need and care until her fortune and credit also were exhausted, and final ruin could no longer be averted. She saw her last son, embittered through disappointed hopes, sink into an early grave, but her constancy, her unwearying help and self-sacrifice, enabled Krupp to attain at least a certain technical success, and thus to lay the foundation upon which the following generation could successfully continue the struggle for final victory. In her old age she lived to see the first success of the Cast Steel Works now managed by her grandson Alfred Krupp, she lived to see the first modest workshop rise and expand into manufacturing works, and died in 1839 with the consolation that her sacrifices had not been in vain.

After the dissolution of the partnership with the Kechels, work at the factory had been restricted to what was absolutely indispensable. File making was altogether suspended, and most of the workmen were dismissed. Beside the overseer, only one hammersmith and one founder were kept on. Through forging jobs for other works, *e. g.* for the small-arms factory at Saarn, by anvil repairs, and steel-refining jobs, the hammer was utilised, and the works kept going, but besides this work Friedrich Krupp personally went on experimenting in order to improve the steel-casting process. In this way the works dragged along on a very modest scale, till about the middle of the year 1815 an accidental cirumstance gave a new turn to Krupp's plans. At this time a notice was published in several papers, among these also in the "Allgemeine Politische Nachrichten", in which the Prussian Chief Mining Office announced, that the steel manufacturer Friedrich Nicolai had been granted a patent for the manufacture of cast steel according to a process invented by him. Referring to this notice Nicolai himself had advertised that for a term of 12 years he had been granted "the exclusive right of making cast steel according to a process and by a composition of his own invention, for the provinces of the Prussian kingdom situated between the Elbe and the Rhine". Nicolai, who was a native of Hanover, and who styled himself a Prussian Captain of Hussars, a title which he might have acquired in some volunteer corps, had formerly been domiciled in the county of Mark, and had there attained a certain reputation for making machinery for the textile industry. He too had afterwards joined the ranks of those men who were haunted by the idea of inventing cast steel. He had been experimenting at the "Karlshütte" near Einbeck, and had treated with the authorities at Berlin as to the utilisation of his invention. On the grounds of experiments carried out before them, in which the secret of the composition of the charge played a great part, he had succeeded in obtaining the patent published in the papers, and a sum of 4000 Reichstalers by way of a subsidy. The patent had been granted on the condition that within a year the process should be carried out on a regular working scale. Beside this state subsidy, which he had already partly used up, Nicolai had no means at his command to enable him to carry on a cast steel factory on his own account. He therefore was on the look-out for a partner, possessed of the necessary means, and if possible also of suitable works, since the period of one year within which he had to put into practical execution the object of his patent, was a very limited term. It was probably with the above intention that Nicolai had come to Essen, inspired with the idea of seeking a partnership with Krupp, to whom he had been introduced by Dinnendahl, a friend of the Krupp family. On the one hand, Nicolai found all his suppositions realised here, and on the other, Krupp also, in spite of his bad experience with the brothers von Kechel, had an interest in joining his cause with that of Nicolai. He had indeed, after the progress he had latterly made, gained sufficient confidence, that he might reach his goal by himself, and his eventual success proved, that he was right. He could, however, not conceal from himself the fact that Nicolai might easily frustrate his attempts, or at least impede them very considerably, that more particularly Nicolai's patent might prove a serious obstacle to the realisation of his own plans. What proved final in Krupp's resolution, was the fact that Nicolai seemed in a position, and indeed undertook the distinct obligation, to put in a capital equal to the value of Krupp's works at that time.

So there was much to favour the partnership on either side; Nicolai and Krupp soon came to terms, and on the 18th of July 1815, the two partners signed an agreement for the common management of the Cast Steel Works as the firm of Nicolai & Krupp. By this arrangement each party engaged himself to communicate to the other whatever knowledge and experience he had. Nicolai ceded his patent to the partnership, undertook the technical management of the works, and was granted residence at the Walkmühle and the usufruct of whatever that property produced. Krupp, on the other hand, was charged with the commercial part, and reserved for himself the right of deciding in common with his partner all matters concerning the management of the works, any necessary changes, and any extensions of the buildings or plant. Profit and loss should go in equal shares, while all working expenses or the cost of any extensions should be booked to the account of Nicolai until the latter's share was equal to the value put in by Krupp, calculated at a moderate figure. The main point of the arrangement, by which Krupp meant to protect himself against any eventualities he had experienced with his former partners, was Nicolai's obligation:—"to produce without any previous failures, and from the very outset of manufacture, cast steel of such perfect quality as was possessed by the product approved of by the Royal Prussian Chief Department of Salines, Mines and Iron Works at Berlin, under the date of June 3rd of that year, according to the notice in number 55 of the "Essen News", that is to say:—that the cast steel should be both weldable or unweldable, and possess the qualities of the best English cast steel, and that the composition of the charge for one pound of such steel should not cost more than one Stiver of Clevish currency." Regarding the Prussian patent granted to Nicolai, Krupp believed that he could trust him absolutely on this point, but here again he was disappointed, and much more grievously than he had been by the brothers von Kechel. It was only the firm confidence that Nicolai actually possessed the pretended knowledge and pecuniary means which could induce Krupp to give up his rights of property on the works, which he had reserved for himself with the Kechels, until their shares put in to the business should be equal to his own. The arrangement signed by the partners could only become valid after it had obtained the approval of the General Administration of Mines, Salines and Iron Works. This approbation was granted, with the restriction, however, that Nicolai was forbidden, in accordance with the stipulations under which the patent was granted, to make any communication to Krupp relating to his process, as had been provided in their agreement. This was a severe blow to Krupp, as he was thus precluded from any share in the process of cast steel making.

Immediately after the conclusion of the agreement, Nicolai and his family moved into the residence assigned to them at the Walkmühle. Here Nicolai's first business was the change and rebuilding of the melting furnaces, which was necessary for the intended production of cast steel on a larger scale. To the right and left of the big chimney three new furnaces were put up for one crucible each, to hold 25 pounds of steel. As another innovation, two heating furnaces were erected for twelve crucibles each; by such preliminary heating of the crucibles the melting process could be considerably shortened. Melting was begun in November 1815, and in an advertisement in the Essen paper "Allgemeine Politische Nachrichten", the precursor of the "Rheinisch-Westfälische Zeitung", cast steel was offered at the rate of six Good Groschens per pound (24 Good Groschens = one Taler). Instead of cemented steel, the crucibles were now charged with raw steel from Siegen, and with iron scrap. The flux was a mixture of ammonia, potash, borax, resin and red chalk. Nicolai was assisted in the melting by his youthful son Ludwig, who in his father's absence undertook the business alone, but neither of them could produce any results at first. Nicolai himself went to Berlin in November to obtain facilities from the Chief Mining Administration for the supply of coal, and to raise money. He failed in both objects, yet on his return in February 1816, he brought home considerable orders for cast steel in bars, for coining dies and rolls. So the works at length had orders, but no cast steel to execute them, and at this point they remained for a long time to come, to the great disappointment of Friedrich Krupp who had believed himself at length so near the goal. The ingots that Nicolai had produced before his journey had proved no good for use, they were either full of blisters, or they showed cracks during forging. In spite of many trials his son did not succeed any better. Work was therefore suspended until Nicolai's return, but neither could he produce any ingot fit for use now, and his melting process proved an utter failure. This was a fresh blow to Krupp, all the more serious because Nicolai also proved unable to fulfil his engagement to pay in the capital stipulated by the agreement. After having put into the business about 2200 Reichstalers, which sum evidently was what was left over from the subsidy he had received from the Prussian Government, his means were entirely exhausted, nay, he even asked for advances from Friedrich Krupp and his mother. Krupp at first tried to assist his partner, who evidently lacked all practice in metallurgical work, by his own experience, because he thought he saw the mistakes Nicolai made. The latter, however, refused such assistance. In view of the severe stipulations of the agreement, he very likely feared that by accepting Krupp's propositions he would admit his own incapability. Just as the brothers von Kechel before, he attributed his failure to the manufacture of the crucibles, which Krupp in the meantime had essentially improved; and asked for crucibles of graphite of Passau. But when Friedrich Krupp saw his advice despised, and when his warnings to pay the instalments for which Nicolai was in arrears, also remained unheeded, urged by his own financial difficulties, he brought things to a speedy close. He was entitled to do so according to the terms of the agreement; it gave each partner the right to dissolve the engagement "in case manifest loss of itself put an end to the enterprise, and if its continuation proved to be to the partner's detriment rather than benefit." In April 1816 the letters exchanged between the two partners began to show an irritated tone. Krupp requested Nicolai to repay the money advanced to him; he reproached him with having violated their contract by going in for expensive experiments which had not produced one single pound of cast steel. Nicolai retorted by asserting that Krupp had prevented him from proceeding according to his own experience. He avoided any explanation with Krupp by word of mouth, and the mutual terms, from being those of friends at first, quickly developed into open hostility. Krupp now openly accused his partner of being incapable of making cast steel, either in Passau crucibles or of his, Krupp's, own make. Nicolai finally even tried to interpret a plot of the workmen, who bore him ill-will for having their wages withheld, a plot which had been directed against him but had failed in its object, as "an attempt on his life". He gave the matter a dramatic aspect, and informed Krupp that he had asked for an examination of his cause by the legal authorities. Krupp now proposed himself to have the suggested examination, which took place in May 1816, and which turned out absolutely crushing for Nicolai. Nicolai's cast steel was pronounced to be unfit for use, and Nicolai himself was declared ignorant of the art of making steel; on the other hand the examining committee pronounced their approbation of the qualities of Krupp's crucibles, and of his method of melting. Krupp now forced Nicolai to leave the Walkmühle, and at the same time lodged a complaint against him. Thereupon the works were temporarily closed and put under seal, pending the sentence on the respective rights of property. After three months the works were returned to Krupp. The lawsuit had to be carried through three appeals, and it was only in 1823 that the Chief Tribunal definitively passed sentence in favour of Krupp. The partnership was annulled, and Nicolai condemned to pay all costs. Only the fact that Nicolai was absolutely destitute of means, prevented Krupp from suing him for damages. He demanded, however, that Nicolai's patent should be cancelled, which demand was only given suit in 1824, after Nicolai's case had been lost in the third and final hearing.

The result of this short union, which had, so to speak, been forced upon Krupp in the first place in consideration of Nicolai's patent, was again very depressing for him. He said himself, that the disappointment he had through Nicolai, had been the severest blow he had ever received, and, indeed, the partnership with Nicolai proved more fatal than that with the Kechels. Once more the factory had been working a year without returns, after work had been entirely suspended for several months; the costs of the fruitless trials, which had by no means been covered by the capital Nicolai put in, had reduced Krupp's finances to a still lower state. But apart from material losses Nicolai had, in another way, brought serious injury upon the works. Relying on Nicolai's assurances, promises had a second time been made to the customers, offers had been sent out, and orders had been received which could not be carried out; for the second time therefore the confidence of the public had been shaken. Besides, by the restrictions attached to the patent, Krupp had been excluded from taking any part in steel making himself; he had been prevented from suggesting improvements which he was longing to make, and which he, no doubt, was very capable of making. Finally by the machinations of Nicolai, mistrust had been awakened against Krupp on the part of the Prussian Government, which it took a long time to allay. It was even intimated later, evidently in consequence of Nicolai's defamatory agitations, that Krupp had exploited him, and derived an unfair benefit from his knowledge and fortune, an allegation which was disproved both by the final sentence in the lawsuit, and by the fact that Nicolai was officially forbidden to communicate his process to his partner. As the only gain derived from this unfortunate episode, Krupp might possibly consider the changes that had been applied to the furnaces in the foundry, and the strengthening of his own self-confidence, with which the official inquiry had inspired him. His ability in manipulating the furnaces, and in composing the charge of the crucibles had been acknowledged as being far superior to that of Nicolai, his experience in the manufacture of fire-proof crucibles was already very considerable, the mysterious fluxes commended by his partners, on the other hand, had turned out a fraud, and Nicolai's patent had proved worthless. Krupp was already then, no doubt, fully convinced, as technical men in general also gradually were becoming, that good crucibles played at least as important a part in the cast steel manufacture, as the "secrets" about the composition of the charge, which then was less understood to mean the raw-materials than the "fluxes". When on the 15th of September 1816, after the removal of the official seals, Krupp was permitted to resume work, he could do so with greater confidence than at the time of his separation from the brothers von Kechel. Unrestrained by the stipulations of an agreement of partnership, he was at length again placed in a position to carry on his works as his own master, guided only by his own technical experience. The manner of proceeding which he henceforth adopted, was an invention of his own, and a note from his hand of that time, in which he laid down the main principles to be observed in cast steel making, proved that on the whole he was on the right track. These fundamental principles were, to proceed correctly in composing the charge and putting it into the crucibles, to manage the fire properly, to examine well the liquid metal with an iron rod, to choose a composition for the charge which makes the metal sufficiently liquid yet keeps down ebullition. He does not yet mention the importance of the raw materials, but on this point also he very soon arrived at correct views, using principally, as he did from 1818, the most reliable Osemund iron, that is a very good wrought iron, made of the best ores of "Siegerland", and most carefully prepared. Only under the force of necessity, and then to his own detriment, did he return later on to cheaper and inferior qualities of iron, scrap and such like things. The charged crucibles were put into the heating furnace, and after that into the melting furnace where they were kept for eight hours. They were composed of two parts of graphite and one part of clay. In the matter of refractory material and in the production of coke, Krupp enjoyed a very high reputation. He also made both these articles for the trade and sold them at times in considerable quantities.

Soon after work had been resumed in the autumn of the year 1816, the first lots of cast steel that were more than mere trials, could be delivered. More than five years had thus passed before Krupp's expectations were realised, even in a modest way. These first lots were sold to different engineering works in the neighbourhood, and were chiefly intended for tools. Their price at first varied widely; from 6½ Good Groschens per pound it went up, in 1818, to 10 Good Groschens, then under the pressure of competition, it went down to 8 in 1819, and in 1821 it was again reduced to 6½ Good Groschens.

Friedrich Krupp now returned to his original idea of taking up the manufacture of finished products of cast steel; by way of trial he had it drawn into wire, and after 1817 he undertook to furnish forged tools, such as boring and turning tools. Part of them were still rejected as being too soft, part of them, however, were approved of, a proof that Krupp now was on the right road. For razors, other species of knives and shears, his steel was not yet pure enough, although its fine grain and malleability were favourably commended. In point of natural hardness, however, it proved superior to the English steel and this property became important in its application for tanners' tools, such as shaving knives, &c., which were used without subsequent hardening. The manufacture of these tools was begun in 1817, and for a long time they formed an essential portion of the output. They were the oldest article of the works for the market. During the period from 1817-1826 they constituted 17 per cent of the total sale, and they retained a certain importance for the works down to the 'forties. Also face and side cutters for thimble factories were made, drills, turning tools, and sharpening steels for such tools, in 1818 occasionally also bootmakers' and saddlers' knives. Liberated from the fetters of partnerships, Krupp quickly succeeded in gaining customers, though the number was limited still. Far more important to him became the manufacture of coining dies, and the orders from the State Mints. In March 1817 the commission agency of Hueck Bros. in Herdecke ordered, among other goods, some dies for the Mint. About the middle of that year Krupp offered coining dies made of his cast steel to the Prussian Chief Inspector of Mints, Goedeking, who happened to be then at Düsseldorf for the purpose of erecting a Royal Mint. Although Goedeking distrusted the cast steel produced in that part of the country, he was prepared to give it a trial. This first connection soon developed into personal relations, fruitful of mutual suggestions, and finally into a lasting friendship between Krupp, Goedeking and the Mint Assayer Noelle of Düsseldorf. The first dies for trial furnished by Krupp, proved on the whole a success, and were followed by a second order on the 20th of September. In 1818 the first lots of coining dies were delivered to the Prussian Chief Mint at Berlin, of which Goedeking had become Director since the middle of that year. After the first trial lot delivered in July, a big order followed, which was finished in November. These deliveries formed the beginning of lasting business relations between Krupp and the Prussian Administration of Mints, and were soon followed by orders from foreign Mints. For the objects of these institutions English cast steel was mostly found to be too brittle, German welded steel on the other hand too mild. Krupp's cast steel of that time stood about midway between the two, and was therefore much approved of for coining purposes, for which hardness and toughness combined were required. It was not long before the Mints of Dresden, Darmstadt, Limburg, Cassel, Hanover and other places gave trial orders, and partly joined Krupp's circle of customers. The orders did not always turn out to satisfaction, for the cast steel still sometimes lacked uniformity of quality, yet even from this period of manufacture very favourable opinions are recorded. The Mint Office at Düsseldorf on the 19th November of 1817 gave a testimony on Krupp's cast steel in the following terms:—

> "Among all species of steels made in this country which have been tried by the "Royal Mint of this town in many different ways for the manufacture of coining dies, "the cast steel made by Mr. Friedrich Krupp at Essen is the best. We have not only "found it in every way suitable for the above mentioned application, but also have "found it endowed with such properties, that in many respects it deserves to be preferred "to the so-called Huntsman steel. We bear witness to this fact, which is the truth, and

> "we desire that this invention, so important for this institution, may soon come to be "of such general usefulness, as it deserves."

The Chief Inspector of Mints Goedeking of Berlin adds:—

> "It is with much pleasure that the Chief Inspector of Mints bears witness to the "above."

So at last the difficulties of the years of the debut appeared overcome, and Krupp began to look hopefully into the future, and to foresee the approaching prosperity of his enterprise. The sum total of transactions rose in 1817 to 2000 Talers, and in 1818 to 2900 Talers, in which latter sum the orders for dies made 44 per cent. The number of workmen went up to ten, and Krupp, who was still much engaged in municipal affairs, took in a distant relative, his "cousin" Grevel, as bookkeeper, in order to be in some way relieved of his work. But in proportion as the orders multiplied, the grievances attached to the working conditions of the small hammerworks on the banks of the Berne since their very foundation, were more keenly felt, and forced Krupp to think of means for an immediate remedy, for, since the rebuilding of the furnaces in 1815, no essential improvements had been made. The insufficiency of the water power of the Berne, and of the weight of the hammers, were among the foremost of the shortcommings, the scantiness of water and the slow current of the Berne, and the interruptions of work through drought and frost had repeatedly occasioned a wish to transfer the forge to some other place. In 1816 Krupp's mother had lodged an application with the Mining Administration for a water power on the Emscher, between the villages of Horst and Vondern, yet with no result. In November 1817, Krupp made a second attempt by asking the government for a lease of the two Berger Mills to the north-west of Essen, which had sufficient water and current to allow the erection there of a heavy hammer and a wire-drawing plant. This demand likewise was not responded to, at least not for the present. About the middle of 1818, Krupp had a second heavier hammer of 329 pounds erected at the Walkmühle itself, but it could only fulfil its object imperfectly on account of the slight current of the water; another inconvenience arose from the distance of the works from the town and the coalmine, which considerably augmented the cost of the produce by the expenses of the transport of coal. So Krupp finally made up his mind to transfer at least the foundry to a plot of land belonging to his mother, situated in the immediate vicinity of the town of Essen and of the coalmine Sälzer & Neuack. He meditated a simultaneous enlargement and improvement of the furnaces, in order to be able henceforth to use bigger crucibles. So far, each casting furnished ingots of at the most 15 to 20 pounds of utilisable steel, yet for the orders which he now received, these ingots were just as insufficient as was the hammer to forge them. The erection, however, of a heavier hammer, and of the intended wire-drawing shop in a more appropiate locality, was reserved for the future.

Friedrich Krupp was no longer able to find the necessary capital for the realisation of these wishes out of his own means. The financial burden of his enterprise which now amounted to 40,000 Reichstalers, he had until 1817 borne alone; his fortune, as far as it could be turned into liquid capital, was now exhausted. His relations refused to advance any further moneys for an enterprise which, according to their idea, offered no chance of success, so much the less so as, even after the sale since 1817 had improved, the result obtained was nowhere near covering the expenses hitherto incurred by the buildings erected and the working of them. Krupp alone remained confident that the worst was overcome, and that the works would soon begin to flourish, if only he succeeded in improving his plant, so as to be able to answer the requirements. He was particularly encouraged by the approval he met with on the part of the Prussian Mints, who held out to him the prospect of taking their whole supply from him, if only he proved capable of furnishing steel of uniform quality. The continuation therefore, and the improvements of his works were in the interest of the State also, and Krupp after having sacrificed the whole of his fortune, believed himself entitled to support from this side. So in November 1817 he addressed a demand to the Prussian Government for a loan, free of interest, of 20,000-25,000 Talers, to be applied to the expansion of his works and their equipment. Such an application to the State for support of industrial enterprises was a natural outcome of the notions then prevailing on the subject of national economics, which argued that the State had to exercise a natural guardianship over the economical conditions of life within its territory, and that it was responsible for their development. The interest manifested on various occasions by the Prussian Government in a national manufacture of cast steel, and the subsidy paid to Nicolai, were liable to foster hopes in Krupp, that he too might have a chance of success in this direction. Besides, he argued that the State owed him some compensation, for, had it not been the patent granted to Nicolai by the State that had misled him into a pernicious partnership with this man? Krupp's demand, however, proved fruitless, he was informed that nothing could be done for him before his case against Nicolai had been decided; after that, it might be considered to what extent "reasons and means could be found to grant support to his enterprise". Another application, made in February 1818, in which Krupp exposed the state of his law suit as it was then, was attended by no better success. Krupp had in the meantime begun the new buildings of his foundry, conceived on a large plan, the continuation of which, however, now became doubtful from want of means. He attempted to obtain help at least in the shape of advances. The Chief Inspector of Mines, Gerhard, who had paid a visit to the Krupp works, and had carried away the firm conviction of Krupp's capabilities, interceded in his favour with the Prussian Minister of Commerce. Simultaneously Krupp had asked for an advance for 6000 Talers through the mediation of his patron, the Chief Director of Mints Goedeking of Berlin, but it was all to no purpose. In the opinion of the minister, so Krupp was informed, his enterprise had already received sufficient support on the part of the State through the subsidy granted to Nicolai. The hidden insinuation that Krupp had surreptitiously availed himself of Nicolai's secret was, however, emphatically repudiated by him.

These first demands for subvention explain themselves quite naturally from the views held in those days as regards the part to be acted by the State, but as it was, they were made at an epoch entirely unpropitious for Krupp's wishes. Since the war of German Independence times had changed, and new notions had sprung up as to the guardianship to be exercised by the authorities over the citizen. Under the rule of far-sighted statesmen like von Bülow, Maassen and Eichhorn, Prussia had taken the lead in a number of exemplary legal measures, bearing on economic topics, which did not fail to have a good effect on trade and industry. Canal and inland duties were dropped, the May Law of 1818, according to the words of Heinrich von Treitschke, "the most liberal and natural law of state economy of those days", did away with 67 custom tariffs in the Old Prussian provinces, only maintaining a uniform and modest import duty at the frontier. The free development of all economical forces, unhindered, but also unfavoured by the State, the lowering of prices for the citizen and the farmer alike, was the object of state policy which was not to be modified for the benefit of some individual. Those branches of industry that had only recently sprung up in order to supplant the products of English manufacture, and that were too weak still to stand on their own feet, more particularly the industrial works established in the territories on the western frontier, to which the great Prussian market was still closed from want of means of conveyance, at first suffered severely under the prevailing current of statesmanship. A compensation for them could only come from the union of the various German states into one big country; they could not flourish till the custom barriers between Prussia and the Southern States were razed, till German industry found an outlet into one common German market. But the time for such evolution had not yet come.

So Krupp in the epoch of his greatest distress was left to his own resources. His relatives felt all the less inclined to grant him further aid, because a wealthy manufacturer of "doublé" from Barmen, named Ehrenberg, who had also taken up the manufacture of tool steel, seemed to have been more successful, and had, in Essen, publicly pitied Krupp, who would no longer be able to hold out against his competition. Krupp's friends could not help believing such words, and no longer saw any hope of averting the imminent ruin of his enterprise, and that at a moment, when Krupp believed himself so near his goal, being prevented only by want of means from utilising the technical progress obtained. When finally Ehrenberg was granted a Prussian patent,—which by the way did not refer to cast steel, but to refined steel,—even the Director General of Mints, Goedeking, advised Krupp rather to enter into partnership with this man than to allow himself to be driven to the wall. Krupp, however, still under the impression of the experience of his former partnerships, firmly rejected this proposition. It is likely also that he did not think very highly of the value of Ehrenberg's patent, after his experiences with Nicolai. He did not allow himself therefore to be turned away from the road he pursued. It was through his wife, who had more than once used her influence with their relatives, that he eventually did obtain the capital to continue the erection of the new shop. She prevailed on her father to stand security for the regular payment of interest on a loan which Krupp's brother-in-law von Müller had some time before given him, and which he now raised to 12,000 Reichstalers. By these means, and by once more straining his credit to the utmost, did Krupp manage to carry to a successful end the work he had undertaken. Towards the end of 1818 a small house intended for the residence of an overseer was erected—it is the original home, the so-called "Stammhaus", into which Friedrich Krupp himself afterwards moved, where he resided during the last years of his life, and which to this day exists in its original shape and insignificance, in the very midst of the gigantic buildings of modern times. The building of the foundry went on as slowly as the means came to Krupp, and it was only in the autumn of 1819 that the new shop, a stately massive building of 180 feet in length and 45 feet in width, was roofed in.

## STRUGGLE AND FAILURE.

On the 18th of October 1819 the newly erected foundry started work, and it was, no doubt, with hopeful joy that Friedrich Krupp saw the first fires gleaming in the new furnaces. In three years' work at the "Walkmühle", and entirely thrown on his own ressources, he had furnished the proof of his success in producing a cast steel which, as regards quality, could stand any comparison with English steel. Conscious of this, and seeing new prospects opening through his connections with the State Mints he was inspired with courage to increase his works at the same time as he transferred them to another locality. Instead of six furnaces he had eight now, and instead of his small crucibles, such of bigger size containing 45 pounds of steel. The producing capabilities of the new foundry therefore had more than doubled; also the cementing furnace, the coking plant and the crucible factory were installed in the new building. The deficiencies of the old works had in this way been partly amended. The proximitiy of the coalmine, no doubt, was a great convenience. The insufficiency of the water and consequently of the hammer, however, still remained the same at the Walkmühle, and new difficulties arose from the division of the work between the two installations. Instead of the coal, the ingots had now to be carried to the Walkmühle, and on roads too that for the most part only allowed of transport on horseback. Alfred Krupp often related in after years, and has sketched in pen or pencil, how he, as a small boy, had often made that journey on horseback, the ingots slung across the saddle hanging down in sacks on either side of the horse.—Friedrich Krupp, now principally confined his work to the superintendence of the foundry, yet often, too, his presence was required at the forge,—at any rate, the works being divided between two localities now, such superintendence was rendered more difficult even than before. Another more aggravating circumstance was, that the force of the hammers became ever more insufficient, the heavier the objects became which could be produced, now that his furnaces had been enlarged, and orders came in for such. He very frequently was compelled to have such pieces,—and in periods of drought and frost even the whole produce of his furnaces,—forged under the hammers of other works, and as most hammersmiths in those days were inexperienced in forging cast-steel ingots, this way of proceeding did not improve the steel, nor did the forges like to take on the work either. In any case, the transport connected with it considerably raised the cost, sometimes even at the rate of twenty per cent. A price reduction therefore of his produce, which in face of the English competition ought to have been his main object, could not be obtained in the required measure. It was only in the autumn of the year 1823 that the Government gave their consent to a six years' lease for the Berger Mills, which Krupp had asked for with a view of transferring his hammer forges thither, but the state of his finances was then already too low to allow of carrying out the plan.

Other circumstances supervened to render Krupp's position still more critical after the erection of the new works, they were in part even the consequence of the step. Relying on the word of some influential Government officials, who had promised to intercede in his favour, Krupp had indulged too much in the hope of receiving a Government subsidy. And when this failed to come, he had engaged himself too far to draw back; all he could do was to carry the enterprise through by straining his credit to the utmost. For many years to come the debts incurred in this enterprise, remained a heavy burden to him; at the same time capital was wanting to carry on the work. The men who had hitherto supplied him with pig iron began to make difficulties, and Krupp very frequently had to look out for other sources. The uniformity of the steel produced necessarily suffered from such circumstances. Things sometimes went so far, that remunerative orders were not executed from want of pig iron. But in 1821 Krupp was released from this precarious position by the Mint Assayer Noelle, who procured him credit with the Brothers Noelle at Lüdenscheid, who carried on works producing Osemund iron. Krupp by this means was enabled to furnish cast-steel samples to the Berlin Mint. Not only Krupp's capital, but also his time and interest were taken up more than was good, by the building work. To this must be added his civic offices, to which he devoted more time than was profitable to his business. Very frequently the work at the Walkmühle was insufficiently superintended, and even the best of the customers frequently had to make complaints as to the quality of the steel and the want of punctuality in furnishing it. So it happened that the year 1819 was marked by a strong decline, which could not quite be made up in the following year. The annual total of business done went up but very gradually, and only in 1823 reached the figure of the year 1818, with its amount of 3000 Reichstalers it even exceeded it by a little. The great success, however, which Krupp had so hopefully expected for the new buildings, he was not destined to live to see.

During the period between the years 1819 and 1823 the development of the works was unstable and desultory. Although on the whole a slight movement upwards may be noticed, a straight and determined march forward along the line laid out, however, was wanting. Under favourable circumstances, energetically pursued, the custom of the Mints alone might have sufficed to secure the future of the enterprise. Instead of that, Krupp took up in quick succession one new product after the other, and in so doing, squandered his forces, feeble as they were already, and frequently neglected older relations in favour of new things which seemed to promise richer prospects to his enterprising spirit and lively imagination. But, taking it on the whole, from no part of his custom did Krupp meet with so much recognition of his endeavours, so much favourable disposition to promote his cause by friendly criticism, by recommendation of his goods and by intercession in his favour with the Government, as he did from the Prussian Mints at Berlin and Düsseldorf. It was on their recommendation that the Dresden Mint gave Krupp's coining dies a trial, which, at length, had such good results, that the Mint Assayer Studer compared Krupp's steel with that of Huntsman. Trial orders were also received from the Mints of Hanover, Cassel, Limburg and Darmstadt, even from the Imperial Head Mint at Vienna. Already in 1818 Krupp had made an offer to the Mint at St. Petersburg, and in November sent thither eight dies for trial. But the above mentioned decline of the year 1819 considerably disturbed these connections. New customers could not be found, and the annual total of transactions, which had shown such a hopeful upward tendency, rapidly went down again. A particularly severe blow, which Krupp experienced in 1820, was the small amount of transactions done with his two principal customers, the Mints of Berlin and Düsseldorf; it was due to their having no work themselves. Another circumstance supervened, the foundation of a cast steel factory by the Prussian State, based upon a process invented by the Royal Mining officer Krigar, who, on a journey of inspection, had studied the method of the English works. When Krupp heard of this foundation, he at once wrote to the Government Chief Inspector of Mines Gerhard, and offered the State his knowledge and experience for an appropriate compensation, alleging that as a rule the foundation of governmental cast steel works was preceded by many expensive experiments, which could be avoided by the acceptance of his proposition. His offer, however, was refused, and cast steel works were erected at the royal expense at the former wire works "Karlswerk", near Neustadt-Eberswalde. Just as Krupp had predicted, they proved a failure, and indeed stopped work after several years rich in losses. But in the meantime, the state workshops were under certain obligations to these government works to cover their supply of cast steel there. Thus it happened that the state itself founded the first enterprise in Prussia which meant a dangerous rival to Krupp. Nay, the ill success of these works was even referred to afterwards as a proof that State subsidies were no proper means to promote industrial enterprise, and that Krupp's request therefore, for the advance of Government funds, could not be granted. To all these adverse circumstances came others which effectually crushed Krupp's last hopes of obtaining large Government orders; as ill luck would have it, the steel of several lots furnished to the Berlin Mint had turned out bad, the high costs of transport to Berlin proved an obstacle. To diminish their expenses, the Prussian Mints again took to making their dies themselves, only supplying themselves with the steel from Krupp, ordered in forged bars. The sale of such steel for coining stamps reached its maximum figure in 1823, at 2000 Talers, which was two-thirds of the total of transactions. But this business did not prove a lasting one either, for the chief reason that the various lots did not prove to be of the required uniformity.

While Krupp's hopes were utterly deceived in this direction, he augmented his zeal to open up new fields for the use of his cast steel. From a price list, bearing the date of the year 1820, may be seen the various branches of manufacture, which he introduced by degrees:—Cast steel was made in bars, blocks or plates; besides cemented or blister steel was offered forged into bars; rolls of cast steel or of a particular cast steel alloy, were sold forged; the plant required to turn them, harden and polish them, was still wanting.—In the way of tools, the price list mentions tanners' shaving knives, in three sizes, sharpening steels for such, unhairing and fleshing knives, pairing knives in two sizes, and sharpening steel for such. Files, which formerly were the only finished produce, are not found in this list. Krupp had indeed thought of resuming this branch of work, but he had to abandon the idea, because he could offer no guarantee for a constant and lasting occupation to the file makers with whom he had to enter into negotiations. Many new kinds of products instead, were soon added to this list, part of which promised large profits and employment. The sale of steel bars to the Mints has already been mentioned; other customers bought cast steel in a comparatively small way only, because its high price prevented its general use. Engineering works which might have proved the best customers for tool steel, unfortunately hardly existed in the neighbourhood, and the few that were there, also found Krupp's cast steel too expensive. The Prussian mail coach workshops at Düsseldorf which consumed considerable quantities of steel were of the same opinion. In Berlin English cast steel could be had cheaper than Krupp steel. It was by this fact chiefly that Krupp had been induced in the year 1819 to take up the above mentioned manufacture of refined cemented steel for tools, springs, and the like in his newly erected works. The circle of buyers of this produce was constantly spreading and towards the end of 1820 the demand became so large that Krupp had to engage a second hammersmith. He had hoped to substitute cemented steel for wrought natural steel, so largely used in the neighbourhood, but this too proved a disappointment. Mr. Goedeking, Krupp's patron, recommended the use of cemented steel for coach springs in Berlin, but he was informed that it could be got cheaper at the "Karlswerk", which, from want of remunerative orders in cast steel, had also taken up this product. A customer from Remscheid, however, placed an order with Krupp for a considerable lot of spring steel; at Remscheid this steel was also used for file making, and the Royal small arms factory at Saarn near Mülheim on the Ruhr worked this steel into parts of small arms, into bayonets and ram rods. Krupp himself repeatedly made tools of cemented steel. Yet after all the trade in this product flourished only during a short period, which was limited to the year 1821, after that, cemented steel only played an inferior part among Krupp's products. The manufacture of cutting tools for bookbinders, for the cloth and leather industries, which was begun in 1820 seemed to be more promising, especially blades of cloth shears were in much demand during a certain period, and Krupp even entertained the idea of establishing particular works for this manufacture. The shears were chiefly sold at

Aix-la-chapelle. During the years 1821-1823 this manufacture reached its climax, and rose to about six per cent of the total output, but after that it rapidly declined. The fact that Krupp had to do the grinding at other works, at Mülheim, Solingen and Remscheid, proved a great obstacle to it. The firm of Henckel and others at Solingen, at various times tried Krupp's crucible steel for making knives, shears, and saws, yet without any lasting success. Attempts were also made to use it for sabre blades, sheaths, cuirass plates, and so forth, but the cast steel of Wald was found to be more suitable for these purposes. A manufacture which afterwards became so flourishing,—that of dies to stamp out spoons, &c., was tried at intervals but proved unsuccessful then. Cast-steel wire, which Krupp got drawn at Altena, was imployed by various factories for piano strings, sewing needles, raising cards for the cloth industry, &c., but here too, its high price discouraged a more general application. In this way attempts were made in manifold species of products.

Cylinders for rolling mills were an entirely new product upon which for a number of years Krupp placed large hopes, and in the manufacture of which he gave evidence of his undeniable technical skill. The trades of the gold and silver smiths, the tinkers, button makers, also the Mints, were in want of small rolling cylinders which presented an absolutely clean surface of very high polish, which at the same time was very hard and very uniform in texture. Steel rolls of a sufficiently high quality did not exist then, and the English chilled iron rolls lately introduced on the continent were not sufficiently pure on the surface, and were sold at prices beyond most people's reach. The demand for such rolls, on the other hand, was so great, that in 1822 the "Society for the Promotion of Industry in Prussia", which had lately been founded, put up a prize competition for the manufacture of such cylinders, made of home raw materials. It is true, that the prize was not important enough to entice industry into any particular exertions, and in the meantime cylinders of any new kind of steel that sprang up, were given a trial. Already in 1817 Krupp had furnished a couple of wrought cast-steel cylinders to Iserlohn, which were destined for a rolling mill in the wire manufacture. In 1818, the Mint Assayer Noelle had engaged Krupp also to make an attempt to produce cast-steel rolls for the coining work. The first couple were sent to the Düsseldorf Mint about the end of that year. They still, however, proved too loose in texture, too irregular in the core, and they generally cracked during the hardening process. But Noelle at once saw the excellent qualities of cast steel for these purposes, and incessantly urged Krupp on to continue his experiments in this direction. It is no doubt owing to Noelle's constant aid and encouragement that Krupp devoted to this branch of manufacture a perseverance which generally was not in his character. In reality these rolls, if they could be made of a uniformly good quality, might have found a large sale for the workshops of mints and goldsmiths. Krupp delivered his rolls in the shape of rough-forged blocks of two or three inches thickness, and had them turned and hardened at the Düsseldorf Mint, since all equipment as well as all experience in this line were wanting. The necessity of producing heavier ingots for such rolls, in particular for a couple ordered by the Berlin Mint which had to be of a larger diameter, played a great part in Krupp's resolution to erect his new foundry. Since forged cylinders very frequently cracked when being hardened, and also because the forging of such big ingots was not possible under his hammer, Krupp during the following years made several trials with castings of a copper and steel alloy. The first couple of such rolls made of this "Composition" was delivered to the Mint of Hannover, where the Mint Assayer Bruel found, that of this kind rolls, well turned and polished, had sufficient resistance even without subsequent hardening. With this alloy Krupp was the first to produce a "special steel". He was also well on the road to solving one of the most important problems of his time by steel castings. But his inconstancy and the low state of his means prevented him from pursuing this road steadily. The copper-steel rolls certainly showed deficiencies still, although several lots gave such satisfaction, that even later, in Alfred Krupp's days, similar rolls were demanded, reference being made to these products of former times. But in order to remedy all these deficiencies, many and continuous experiments and improvements had to be made, and to follow up this, Krupp at this epoch had neither patience nor money. He wanted to see a success that could be realised at once, this to him meant the only possible chance of keeping his business afloat, considering the difficult position in which it was. He therefore soon returned to the old process of forging rolls made of steel. He dropped all other experiments, and contented himself with carrying out the few scanty orders that came in. So this last hope too, gradually faded away. Until the death of Friedrich Krupp only 50 to 60 cylinders of small weight were furnished altogether. The experiments, however, connected with their manufacture had this practical result, that they enlarged Krupp's metallurgical knowledge, and brought him into contact with clever men of the profession. It was left to his son Alfred to take up later on the inheritance of his father in this line, and to make cast-steel rolls for many years the very foundation of his whole enterprise.

Oscillating in this manner between hope and disappointment, from the year 1819 the works dragged on until 1823. The total annual proceeds had again risen gradually from 1900 Talers to 3000 Talers, the highest figure which was ever reached during Friedrich Krupp's lifetime. But what significance could be attached to such a small sum, which comprised an almost unappreciable benefit, when compared to the debt that had been accumulated? If the enterprise was to prosper at all, it ought, to start with, to turn out profits from which the liabilities could have gradually been covered. In reality, however, even in the best years, the receipts could not pay the building and working expenses, not to speak of the interest which had to be paid, or the debts which had to be refunded. On the contrary, Friedrich Krupp had been obliged, year after year, to raise loans, in order to be able to continue his enterprise at all. And the more difficult his financial position grew, the worse the effect became which it had on the working condition of the establishment. It was getting more and more difficult to find the supply of the expensive raw produce, such as Osemund iron and graphite, in sufficient quantities and from first class firms. The works were constantly looking about for new sources of supply, because the old firms had not been paid yet. At last the manufacture had even to resort to material of inferior quality; a varying and uncertain production was the consequence. So deficiencies in the quality of the cast steel, in consequence of a frequent change in the raw materials used, and of an insufficient control over the works, constituted one reason for the very slow progress of the works, both in respect of sale and reputation. A second reason was the smallness of the general demand for cast steel, and the ample supply of cheap English goods. The difficulties that stood in the way of general intercommunication and of the transport of goods, no doubt, contributed much to Krupp's final failure in the face of such competition. Wherever there was no direct communication by water, such as existed between England and the towns of Hamburg, Cologne, Magdeburg, Berlin or Breslau, the whole traffic was under the sway of the mail coach and the carrier. The cost of freight from Essen to Berlin in 1818 still amounted to 21 Reichstalers for the ship pound—165 kilogrammes—and the term of delivery was 30 days. Besides, the opportunities for conveyance were but rare, and without any guarantee whatever. An order for stamping dies, which came in September 1818, could only be despatched from Essen towards the end of November, from want of any chance of conveyance, and on the 11th of December only it was forwarded on from Hanover. Sometimes it would happen that urgent parcels were waiting for months at the agents' at Hagen or Mülheim.

Considering these circumstances, it was not easy to compete with English steel, which enjoyed a widespread custom, and for which agencies were established in many places. Krupp also tried to enlarge the circle of his customers by commissioning agents and retailers, and by publishing notices in papers. But the time that was still left him, was too short, to render any success of importance possible. In March 1818 he advertised a notice of recommendation in the "Oberpostamtszeitung" at Frankfort-on-Maine and probably also in other papers. This step undeniably had a certain good result, in so far as orders came in even from distant parts. In an article which Krupp wrote in the year 1820, in the "Westfälischer Anzeiger" he drew attention to his cast steel, and published a price list of the new works. Other steps tending to improve the sale were again undertaken in 1822, by the issue of a second price list, by sending products to the Society for the Promotion of Industry in Prussia, and by notices published in the reports of the meetings of this society. The opinion which the committee of investigations of this society expressed on Krupp's steel, was very favourable for him. In the main the endeavours to find new customers consisted in written offers, or in the introductions of recommendation from one customer to his friends, or among the circle of those interested. Krupp had repeatedly addressed a request to the Berlin Mint asking for a recommendation to other Mints at home and abroad, or even, should an opportunity present itself, to let them have a sample of his coining dies which they had on hand. Now and then business journeys were undertaken. Friedrich Krupp himself occasionally visited his business connections in the interest of his products, and the equipment of his works. He sometimes even went to Frankfort-on-Maine to visit the fair. Grevel likewise was ordered by him to travel round the industrial districts of the counties of Berg and Mark, to Düsseldorf, &c., and to offer tanners' tools, files, tool steel and rolling cylinders, and to try to commission manufacturers of all places as retailers of Krupp's products. These journeys were not entirely unsuccessful, commission agents for tanners' tools were found in Kreuznach, Coblenz and Frankfort. A firm in Breckerfeld even sold tanners' tools and bookbinders' cutting discs as far as Holland. In the year 1820 dealers at Remscheid had tried to introduce Krupp's tools into France. But the goods were for the most part returned, as they did not answer the buyer's wishes. Especially with tanners' tools, the shape usual in the country played an important part. It is true, that the retail firms sometimes demanded, that their own firm and more frequently the English trade mark should be stamped on the goods. With the object of finding a market in the eastern provinces, a parcel of goods was sent to a firm in Berlin in 1822. About that time Krupp even thought of finding a commission agent at Hamburg, but he gave up the idea on the advice of a business friend there, who held out to him, that he stood no chance against English competition. Ever since 1818 samples had been sent to Saxony, Belgium, Austria, Russia and Switzerland. Orders and inquiries finally came even from rather distant parts of Germany, *e. g.* from Nuremberg, Heilbronn, Frankfort-on-Maine, Darmstadt, Hanover, mostly from the circle of the gold and silver smiths and others connected with them. Many among these customers, as for instance the firm of B. Bruckmann & Co. at Heilbronn, have remained faithful to the Cast Steel Works for many decades after the death of Friedrich Krupp.

Passing in review once more the success of all these endeavours, one may state that up to 1817 Krupp's customers were entirely made up of commercial and trades people. At the end of that year, they were joined by the workshops of the State Mints, which, until the year 1826, that is until the death of Friedrich Krupp, consumed about 27 per cent of the total production. These transactions reached their maxima in 1819 and 1823 when they attained 66 per cent, and 43 per cent respectively, of the total output. The business done with the Mint authorities might have been considerably more important, if it had been possible to execute the orders for coining dies with unvarying regularity, and within the stipulated terms, and if it had not been in Krupp's character, sometimes to neglect old customers in favour of new ones. So it happened that the evershifting circle of private customers expanded only very gradually, their number rose in 1823 to its climax, but soon dropped again, so rapidly that at Friedrich Krupp's death only one third of them remained. Speaking of the local expansion of the market of Krupp's produce during this period, it was limited to the western half of Prussia, as far as Berlin, but chiefly to Essen and its surroundings, the towns about the lower Rhine, and the counties of Berg and Mark. After 1818 the market was further extended to Hanover, Hessia, Wurttemberg and Bavaria. After 1821 also to Baden. Hessia and Wurttemberg in particular, remained faithful customers of the Cast Steel Works during the period of their first modest development. But after all, during the whole period of 1812 to 1826, only 11 per cent of the total of transactions were done with countries outside Prussia. In the first years of their existence, the part attributed to the works seems to have been, almost exclusively, to supply the local market and that of the environs. Through the connection with the Mints, a more extensive and more important sale was obtained for a certain time, and the tanners' tools constituted a current article which found buyers in wider circles, and which, together with the coining dies, established a certain reputation for the products of the Krupp works, of which Alfred Krupp profited afterwards when, on the ruins of his father's inheritance, he started the work afresh for a second time.

It has been mentioned that the slow pace at which business went on, and which after 1823 degenerated into a rapid and irretrievable decline, must principally be attributed to the want of an energetic and intelligent control of the works. Friedrich Krupp himself, since 1821, frequently prevented through his ailing state of health, withdrew more and more from it. In proportion as he did so, his "cousin" Grevel, who since 1818 had been engaged as a bookkeeper, expanded his sphere of action at the works. Neither of these things were for the good of the enterprise. Grevel was intrusted with business journeys, and in the beginning of 1822 was also charged with the control of the works in the foundry, and with the preparation of the crucibles, which circumstance did not contribute to improve the steel. This independent position inclined Grevel, who had now taken residence in the overseer's house at the works, to act arbitrarily which, indeed, became the cause of his eventual breach with the all-too-confiding Krupp. The workmen, on whose trustworthiness Krupp under these circumstances had principally to rely, proved generally faithful, capable, and well disposed, but they were mostly unskilled men, farm-labourers, who had only just received so much training as was indispensable for the tending of the smelting furnaces and the crucible press, and they divided their work between the demand of the factory, the needs of the domestic economy at the Walkmühle, and the cultivation of their small plots of land. Skilled men were only required for filemakers and hammersmiths, they generally came from the counties of Mark and Berg, and beside the overseer and the bookkeeper were the only people engaged at a yearly salary. On the whole, the relation of Friedrich Krupp to his working men was distinctly on patriarchal lines; in times of distress they stood by him, as he stood by them, and during the differences with his partners Krupp had always had them on his side. After 1816, a few blacksmith masters, who lived in the immediate neighbourhood of the works, took work there, among them a certain Marre, who joined towards the end of 1816, and remained in the firm's service until 1848. Very frequently jobs were given to the blacksmith masters to be done in their own shops. A certain number of the founders also remained true to the works, even after the death of Friedrich Krupp. A founder named Paus remained in Alfred Krupp's service until the year 1830. A labourer Wilhelm in der Wiese had closely grown together with the works; he had come to them in 1813, and held out faithfully, in spite of all storm and stress, until 1831. He was literally a factotum, and could be put to any work. Now he helped making crucibles, then he gave a helping hand to the hammersmith, again he was busy at the furnace, or did building work, or worked in the field. When, now and then, work failed at the factory, which occured ever more frequently during the last years of Krupp's life, the workmen were compelled to take a holiday; being themselves farmers in a small way, and home industry being a customary practice then, such interruption of work caused no great inconvenience. But if real distress happened to knock at their door, it was to them a matter of course that their former employer should help them, just as it went without saying, that he could again dispose of them, whenever he wanted to or could resume work. It is one of the most interesting and instructive chapters in this centennial development, to see how from these conditions of the early times, which were based on tradition and on mutual interest, the eventual organisation of the relations between employer and employed at the Krupp's works has developed.

In the 'twenties, Krupp's own personal share in the work was more and more restricted to the correspondence with his far spread customers, more particularly with the technical men of the Mints, with whom he exchanged advice and experiences, and to those measures which were constantly required to keep the establishment growing, in spite of all the difficulties. The pecuniary embarrassment was so great at times, already in 1820, that Krupp hardly saw a way out of it. For many years the help he could best rely on, came to him from the administration of the Prussian Mints, who almost invariably met his wishes, whenever he asked for immediate payment of his delivery, or even for small advances on orders he had received. By this means the establishment could be kept at work, in some way at least. To carry out thorough changes, or extensions and improvements which alone could make the establishment more profitable, would have required far more considerable means. Yet after all, Krupp's high aspirations, his spirit of enterprise, and his optimism were not yet broken. About the middle of the year 1820 he made a second application to the Russian Ministry of Finance, offering his cast steel and his steel cylinders, and asking permission to establish cast steel works in Russia. He hoped to find there more easily the support of the Government, without which he no longer saw any possible chance of success. However, the answer he received was, that a perfect steel, cheaper than Krupp's new cast steel, was made in the country itself, and that the Russian Mints used rolls of a very good and resisting cast iron, that is to say English chilled cast-iron cylinders. Krupp made another attempt to obtain financial assistance by addressing a request to the Society for the Promotion of Industry in the Prussian States, which had expressed a favourable opinion on his steel. Goedeking also recommended this application, but the answer he received could only induce Krupp to drop any hopes coming from these quarters, for he was neither disposed to comply with the statutes, which demanded a description of his inventions, nor to take out a patent for it. In the summer of 1821, he received a visit from the president of the aforesaid society, the well known State Councillor Beuth, and the Councillor of the Board of Revenue, Scalley, of Berlin, who by their visit confirmed the interest which the Government took in his works. Unfortunately their visit occurred during a most unfavourable period, since just then work had been suspended at different times, from want of funds. The inspection therefore of these gentlemen led to no favourable consequence for Krupp. Yet friends and relations, in particular his mother, still went on assisting Krupp on various occasions, and sometimes with very considerable sums. But the evergrowing burden of his debt threatened more and more to overthrow his establishment. During these years courage sometimes failed him, and he writes to his friends so despondently that Noelle tried to stir him up with rough words and even reproaches. So, in answer to Krupp's complaints that no one would any longer let him have pig iron on credit, he wrote in December 1821:—Good gracious, my dear Krupp, you feed a lot of people who suck the blood out of you, are they altogether not any good to help you to an order of cast steel. I dare say there is sufficient good iron to be found in Essen to produce a few hundredweights of cast steel, even if you should find old nails and melt them down.

When in the spring of the year 1823, in Krupp's lawsuit against Nicolai, sentence was passed in his favour, he once more tried to obtain an advance from the State Funds. At the same time the Chief Inspector of Mines Gerhard made an application in Krupp's favour to the Ministry of Commerce, but Krupp's written request did not even reach the hands of this personage, as the Government authorities at Düsseldorf already refused to pass it on, alleging that all applications of a similar nature had been answered in the negative by the Supreme Authorities at Berlin. So Krupp had finally to abandon all hopes of ever being granted pecuniary aid from the Government. It is only too natural that the collapse of so many hopes and expectations should have had a paralysing effect on him, and it was just as natural that, the sadder the aspect things assumed in his private sphere of action, the more his mind turned away from the things which to him only meant sorrow, self-reproach, worry and disappointment, and that he preferred to devote himself to his public duties. This turn of mind, however, was most detrimental to the works, more particularly so as during the critical years of 1823 and 1824 he was absorbed in town affairs even more than before. Over and above this, already since 1821, his physical and mental powers had begun to show signs of exhaustion. For some years past he had often been ailing; in the autumn of 1823 he went to Schwalbach to restore his health by a six weeks' cure. It had not, however, the hoped for result. At this time, the works had gone down so far that their decline almost reached absolute collapse. The slight increase which the total output experienced during this year, may be looked upon as a last flickering before the end, perhaps due to the exertions made in former years rather than as a sign of a new rise. At the end of the year, the works came to a complete standstill, and things remained in this state until the summer of the next year. Want of money and discouragement paralysed Krupp's forces, and made him henceforth incapable of recovering the energy necessary for decided action. Even the visit of the Mint Official Kleinstüber from Berlin, on whose testimony large orders might possibly depend, proved unable to rouse him. He seems at this time to have fallen into a deep lethargy, a magnetic sleep, as his friend Noelle said. Most of the workmen were dismissed; the sale was reduced to one third. In former years Krupp had always succeeded, in some way or another, in finding the capital necessary to cover the most urgent expenses, but now all sources were dried up. From time to time he once more made attempts in various directions. To Overbeck who supplied him with Osemund iron, he even offered a partnership, a step which only a few years ago he would have absolutely declined. He asked for a loan out of the Funds of the Miners' Union, but he failed here as he did everywhere; he had lost all credit. The sole help Friedrich Krupp met with in these last years he found with his mother, who sold plots of land, reclaimed capital lent out on mortgage, forewent payment of interest or of loans fallen due on the part of her son, stood security in his favour with supplying firms and creditors; in fact, she sacrificed all to her son's interest. And it is touching to see, when her own fortune had been almost entirely drained, how she helped her son until the last, with small sums, even with a few Talers. But with all this, she was unable to check the course of destiny; Krupp did not recover his old energy and elasticity. His family had grown, and at the same time also his domestic cares and his responsibility for the future. His first-born daughter Ida was followed in 1812 by his first son Alfred, who now helped his father, and who afterwards was called upon to carry out his intentions, and to complete the work he had begun. Two more sons followed in 1814 and 1820. In this way the burden of finding the means of subsistence for his family had increased, so that at last the commonplace care for the provision of daily bread stifled the enthusiasm for the great work of which he had dreamt. Under the weight of such burdens, and in consequence of his illness, Friedrich Krupp gradually fell into an embittered and distrustful mood, which betrayed itself in unjustifiable lawsuits and differences with his business connections and employees. So in October 1824 the overseer Tacke, who had been in the service of the works from the very beginning, was dismissed. When Tacke left his residence at the Walkmühle, Krupp's relations saw a welcome opportunity to induce Krupp, now a sick man, to lay down his offices in the town's service. They proposed to him that Grevel should go to live at the forge, and that he and his family should move into the little house at the steel works outside the town, which would then become disengaged. Hoping that the country air would improve his health, and seeing that he could exercise a better control over the works, he accepted the proposal. So in October 1824 he moved with his family into the miserable little house he had built six years before as an overseer's residence. This thus became the "Original Home" of the Krupps. At the same time he gave in his resignation of all town offices. Krupp's mother moved with the family out into the little house and remained there until 1825. At the end of 1824 Krupp was laid on the sick bed, from which he did not rise until the September of the next year. The work at the factory continued on a most moderate scale under the management of Grevel assisted by Krupp's wife and mother, who had already taken a part in the business before. Towards the end of 1825 Grevel too left the works in order to set up for himself. He also departed after a quarrel with his master, whose temper was getting more and more bitter. After this Friedrich Krupp, whose health about this time was declining more and more to a lingering death, had to rely on his son Alfred alone for the control of the men. The boy was then between thirteen and fourteen years old, but he was developed far beyond his age, in energy, practical sense, and decision. Already in October 1825 he had acted in his father's place in some business quarrels. At Easter 1826, Krupp took his boy away from school and utilised the short interval he had still to live, to introduce him into the main operations of the manufacture; he showed him how to make crucibles, how to prepare the composition and charge for the steel, he instructed him in the manipulations connected with the furnaces, and imparted to him all his experience; and whatever he could not show to Alfred himself, the boy soon gathered from the workmen in his daily intercourse with them, that is, of the few that were still were kept on, and who now transferred their regard and attachment from the father to the son. Before the end Friedrich Krupp made one more exertion. During his long illness of 1825, his mind had been occupied by the question of rolls, and he decided to take a part in the prize competition on the question of chilled cast-iron rolls, which had not yet found any solution. Goedeking and Noelle furthered his plan in every way, by advice, recommendations, and offers of advancing the necessary means. But Krupp no longer had the strength to take this work seriously in hand. It was only in 1824 that he had written to Overbeck the prophetic words on his Cast Steel Works: "This business may in the course of time, when appropriate working funds have been earned or otherwise found, become one of the most important in the State". At that time he was still full of confidence, and even now absolutely unshaken in his belief in the final victory of his cause; but for his own part he had most likely given up all hope, and only looked upon his son as him with whom the future of his works rested. He himself could no longer be of any avail to the enterprise. Work had now come to an "almost complete" standstill. Krupp's name was struck out of the list of those tradesmen who had to pay for a license. The end was approaching, the state of health of the patient was getting worse and worse every day, and was hopeless at last. Dropsy in the chest set in, and on the 8th of October 1826 Friedrich Krupp breathed his last.

It seems almost an irony of fate, that the Prussian Government, which had declined to listen to Friedrich Krupp's many applications for pecuniary assistance, seemed at last to have awakened to the perception that his enterprise, above all others, deserved attention. A Royal Cabinet Order of November 1825, declining the request of a certain cast steel manufacturer Heyder at Ronsdorf, had recommended to the Minister of State von Schuckmann all possible furtherance of the Krupp works, which indeed had supplied to an essential want. The Governmental cast steel factory at the Karlswerk had at that time already been suspended, and the hope of the Government to free themselves from the English cast steel monopoly by works of their own, had proved vain. But it was too late now for Krupp who did not hear any more of the turn things had taken, and that Cabinet Order never had any practical result for the cause of the Krupp works.

## FRIEDRICH KRUPP.

In the very prime of life, not quite forty years old, Friedrich Krupp was snatched away from his life's work, at a moment, when a healthy man's full vigour seemed necessary to rescue the enterprise from ruin. At a first glance, and judging from apparent circumstances only, the life of this man, promising such great things at the outset, seems to have ended in absolute failure. During the last years no progress had been made, they had only been rich in disappointment, and when Friedrich Krupp wrote his last will, the evolution of the Cast Steel Works had reached its lowest point. But with all this Krupp had never for one moment, even in the saddest days, abandoned his faith in the cause he had undertaken, and in his last will, he bound those whom he left behind him, to the duty of carrying on his work. He himself had not been able to reach the great goal which had been the dream of his life, but that technical success which was only to mature in future years, he had been able to attain, and this will be his lasting merit. The firm and unswerving confidence he had in ultimate success, he handed down as a legacy to his wife and children, and it has essentially prepared the way for the final victory of the next generation, who had "more luck", as Alfred Krupp put it in his modest way. So Friedrich Krupp's lifework became, to use the fine simile of his son "seed for a late harvest", and if the works whose foundations he laid, still bear his name to these days, this is only just.

No picture, no drawing has transmitted to posterity Friedrich Krupp's outward appearance, but his nature and character are distinctly reflected in his fate and career, in writings and sayings of his friends handed down to us. Friedrich Krupp's character was not such that its features blended harmoniously into one uniform and harmonious picture. Just as in his outward life will and action often were at variance, so there was a discord in his inner nature; he was intellectually endowed with gifts far above the ordinary average, he had a keen understanding, a quick power of perception, and a most lively imagination. He was prompt to act and energetic to a high degree. But just as his power of imagination was not controlled by a notion of what was attainable, so his energy lacked perseverance. This discord in his nature became stronger with time, a tragic feature in Friedrich Krupp's character, and in this is to be found the principal reason why reality was so often left far behind the high flight his imagination took.

These things naturally were less strongly accentuated in Friedrich Krupp's early years. His lively spirit, his quick fancy, and the exuberance of his temperament made him liked by everybody, and above all made him a favourite in the social circle of his friends. His talent as a narrator, and the wit that stood at his command made his conversation charming, and Krupp himself at once the centre of a cheerful company. We hear in a letter of his brother-in-law Bohnstedt, that he was often apt to overstep the limits of good taste, and to let his good humour run away with him. While the writer finds fault with this, he is ready to admit that Krupp's social talents were very much appreciated. All his life long Krupp had preserved the liking for merry company which was bred in him, and could be easily satisfied by the lively intercourse which existed among the members of the numerous and widespread family. Also with men, whom he met in his business relations, such as Dinnendahl, his first partners, later on Noelle and Goedeking, he was very soon linked in friendship. He hospitably received them in his house, and to many of them he remained a friend all his life long. Amiability of an effusive nature, and inborn cheerfulness, combined in him with absolute integrity of character; he was upright, just and confiding. His frankness was also recognised by those who did not approve of all the manifestations of his exuberant spirit. Even by one who was usually more inclined to find fault with him, a testimony is on record that Friedrich Krupp was greatly esteemed for his strict candour in matters where right or wrong were concerned. To these traits of his character were added an earnest desire to improve his knowledge of the various scientific subjects current in those days, and a lively interest in the manifold questions of practical life. So Friedrich Krupp was not only an attractive personage, but even in his younger years was considered a clever man, well fitted to hold a leading position in life. The circumstance that the management of the Gutehoffnungshütte was entrusted to him, when a youth of hardly eighteen years, may be adduced as a proof of it, and even more so the fact that his fellow citizens conferred upon him the office of a town councillor at the early age of twenty five.

Friedrich Krupp was well conscious of his own talents and capabilities, and even in his youth, there are signs of his inclination for art and of his ambition. This bent is clearly visible in a diary in which poems and reflections of his early youth are noted down. It was visible in after life in his marked self-assurance, and in his strong desire to put his person forward. This bent also was a potent factor in the zeal he showed to act a prominent part among the municipal dignitaries of his native town, apart of course from the strong public spirit that animated him. To him, as the offspring of a family of patricians, his participation in the municipal administration was a matter of course, but the many different ways in which he took a part in it, are a strong proof of his marked inclination for public interests and of his enthusiastic devotion to them. As a member of the committee for the settlement of soldiers' quarters, and of the allowances to be made for them, and as an adjutant of the "Landsturm", he knew how to enforce the necessary impositions on the citizens with a firm but equitable hand. He undertook the department of municipal road making and building of highways. As chief of the fire brigade he found an opportunity of applying his knowledge in matters relating to building and laying out the town plan. In all these offices he fully justified the confidence his fellow citizens had placed in him, and he well deserved the vote of thanks that was expressed to him on the occasion of his resignation in 1824, in a letter which he received from the burgomaster Kopstadt. It must be admitted, however, that the way in which he became ever more engaged in municipal matters, did not contribute in the end to the prosperity of his own enterprise. Even when his strength began to fail, he could not for a long time make up his mind to resign all his municipal offices, the result of which was, that rather than give up his position as a town councillor, he neglected his duties to his establishment, and left the work there in the hands of others.

Leaving out of consideration, however, his last and worst years, it must be admitted that Krupp in his own enterprise showed plenty of zeal, talent, and practical ability. He did so already when he was at the Gutehoffnungshütte, he did so again in his widespread and many-sided import business, which he founded at the age of twenty-one, and in the management of which he displayed an unusual commercial sagacity and spirit of enterprise. In conducting this business he could not tread the beaten track; it required rapid decisions that kept constant account of the ever-changing conditions of frontiers and consequently of custom duties, and it was perhaps this very circumstance that induced him to take it up. So much is certain, that difficulties connected with an enterprise were more likely to allure than to deter him, a feature of character, by the way, which will be found again in his son, only in a much more pronounced manner. There is no doubt that in Friedrich Krupp's decision to found the Cast Steel Works, the difficulty of the problem, that already had overthrown so many an inventor, played a very great part. His self-confidence did not allow him to stop at any considerations, the practical and technical knowledge that he still lacked, he believed himself able to acquire in a short time, all the more so, as he had already gained some considerable metallurgical knowledge at the Gutehoffnungshütte. It was proved in the end, that he did not overrate himself, for in spite of his successive partnerships, it was finally he himself who first succeeded in Germany in making cast steel on a working scale. In the manufacture of crucibles, he even attained an extraordinarily high standard of perfection for those days.

But as soon as the question was, to carry into practical results what had been technically solved, Krupp's nature gave way altogether. He has over and over again proved that he well knew how to set about a thing, how to further it cleverly to a certain degree, but that he was not the man to stick to it in spite of obstacles, and to carry it to a good end. Whatever he attacked, he went at first with great zeal, and he was ready to do any work that the business required. He was quite willing to stand up at the fire or to do any work at the smelting furnace, a fact to which his son Alfred has afterwards testified. His inborn eagerness for work, and his very lively fancy much given to anticipate results, easily made him overcome the difficulties of the beginning. Any hope that dawned, he took for a certainty. But when the first fire of his enthusiasm had gone out, when reality proved more difficult to attain than his wishes and hopes had anticipated, his interest would quickly abate, and repeated disappointment, stifle his strength. He then turned to new ideas, and gave up plans, that only a few months before had held out to him the most alluring prospects. Certainly, in the beginning, his sanguine temperament stood him in great stead, by it he was inspired with readiness to act, and with that daring which enabled him to take up an idea, even if its practical realisation could not at once be discerned. It was from this source also, that he drew the energy with which at first he confronted the many disappointments and difficulties that ever arose afresh. But in the end, his all too hopeful temper did not prove a blessing to him. Too often his optimism carried him away to exaggerated expectations; he left out of account the many troubles and sacrifices that were so particularly necessary to obtain even the smallest progress in the work of introducing cast steel. He had clearly foreseen in a way the possibilities of a great future for his works, the chances of their expansion, if circumstances turned out favourable. But already after the first small success lay within his grasp, the great goal was only to be reached after many decades of hard and unrelaxing work. Many measures also taken in the works, and to be considered as having been applied either too early or on an unwise scale, may be explained from the same motives. Krupp lacked the sense of what was necessary, what was possible to realise.

Besides the obstacles to success that are to be found in Krupp's character, there was the danger that he frittered away his strength by the multiplicity of his interests. He devoted, no doubt, more time to the service of his native town than was good and useful for his establishment, and even the work he gave to his own business, soon showed an unsteadiness which increased in proportion as his health broke down. He became more and more possessed of a nervous restlessness, he jumped from one thing to another, started new technical experiments, now here, now there, only to abandon them again very soon after. This want of self-restraint, of constancy of purpose, have in a large measure contributed to the fact that Krupp in so short a time, and without any lasting success, exhausted capabilities which at one time had entitled him to hopes of great achievements. From the year 1823 he became a physically broken man, and no hopes were left to him for his own person. But to the great aim of his life, which once had appeared so near to him that he thought he could seize it with his hands, and which now seemed to have vanished away into the far distance, he even now still held on with desperate enthusiasm. The idea of giving up the works entirely, if he ever entertained it for a moment, he always rejected, even on the brink of his grave. His hope in a better future for those whom he left behind him, and for his works never forsook him. And eventually he has proved to be right, in this as well in his faith in the great importance of the cause he had undertaken.

One feels inclined to ask, how it is that Friedrich's son should have succeeded where he himself had failed. If one wishes to do justice to the founder of the Cast Steel Works, one must admit, that the circumstances of the times were by no means favourable to the newly founded enterprise. When it had hardly passed out of the stage of the first experiments, one of the essential conditions of its success was taken away, by the continental blockade being raised, and the powerful English competition being again admitted. After the peace, the complete exhaustion of all economic forces for a long time prevented any quick recovery of industry. In the meantime the disappointments Friedrich Krupp had experienced with his partners, had drained his means, so that financial distress set in at the same time as his first success. But Alfred Krupp too had to fight against most serious difficulties, and although circumstances gradually took a more favourable aspect for him, nevertheless for a long time, considering the state of utter ruin in which the inheritance of his father was, when he took it on, things were no more favourable to him than they were during the last years of his father's life. It was the great good fortune of the enterprise that, although Alfred's health was not always good, he was always able to hold up physically against all exertions and cares, whereas his father's strength soon failed. Yet, at the very root, the reason for the fate to which Friedrich Krupp succumbed must be found in his own character. With all his rich talents, he was not the man to stick to a goal he had once fixed his eyes on, with unswerving constancy. And the want of endurance and foresight, of perseverance and self-restraint even caused that which he had attained, to slip away again from his grasp. The brilliant gifts and the hopeful temper of the father, may be discovered even in a higher measure in his son Alfred, above all, his promptness of decision and his bold daring, his great spirit of enterprise, and his lively imagination. But while these qualities prevailed so strongly in Friedrich Krupp that they upset his equilibrium, Alfred Krupp never lost the sense of what could be attained and never lost sight of the necessary precaution when dealing with technical innovations. The gifts wanting in the father, the concentration of strength on one great task, the unrelaxed perseverance nearing the goal in view step by step, the unintermittent application given even to small things, these were the intrinsic and prominent qualities of the son. In this happy union of qualities and capabilities which partly were of an opposite order, is to be found the secret of Alfred Krupp's success. That those properties, however, which so wonderfully counterbalanced the impetuosity of his nature, could develop so strongly, is due the fact, that they not merely reposed on a natural disposition, but that they were essentially an outcome of the strong impressions he had received in his early youth. He had been a witness to the fatal struggle of Friedrich Krupp for the continuation of his works; the father's shadow fell as a warning on the long life of the son. Alfred Krupp has more than once confessed this, and many of the warnings and admonitions that came from him during the last years of his life, seemed as though they had been written under the immediate impression of those sad days. So in this sense also Friedrich Krupp had not lived and fought in vain. In the summing up of this first chapter of the history of the Krupp's works, it is a consolation to think, that the tragic end of its founder became, more and more as time went on, by the influence it had on the successor, a cause and agent of the prosperity of the enterprise.

# ALFRED KRUPP.

## 1826—1848.

On the 8th of October 1826, Friedrich Krupp departed from this life, disappointed in all his hopes. In his will he made three days before he died, he settled that the works should be carried on, that his wife and children should be his universal heirs, and that his widow should be the guardian of his children. So till his last breath he gave evidence of the confidence he had in his creation, and in those who bore his name. But what was the inheritance that he left to them?

The debts far exceeded the fortune, so that the widow ventured to take possession of the heritage to which many responsibilities were attached in her own behalf, but she declined to accept it for her children, who were still minors. The works, according to Alfred Krupp's own testimony, consisted merely of empty buildings; there were no raw materials left, the furnaces and hammers had suspended work, and credit was no longer to be found anywhere. There had been no orders for months, and the number of customers had continually grown less. Krupp's name had even been struck out of the list of the rate-paying trades people. Over and above this, English competition had of late years become very powerful, and a new rival sprung up in another quarter, viz Ehrenberg's Patented Westphalian Cast Steel Factory, which had been founded at Essen in February 1826, by Krupp's old adversary.

It required indeed a great deal of pluck and strength of character, considering the sad condition in which the works were, to risk such a hazardous thing as resuming the business in those times. And a woman, who had a right to be discouraged by the sad experiences of the last years, and who nevertheless undertook the task, deserves all the more credit for it. It appears a duty to recall on this occasion the memory of that brave woman, whose heart in those hard times never grew faint, and to whom thanks are due for the rescue of the enterprise from ruin.

Therese Wilhelmi was only 18 years old when she was married Friedrich Krupp, and her union with the highly respected family of her husband seemed to predict a happy future. Instead of which, years of hardships and sorrows followed, during which she stood by her husband faithful and undaunted during his hard struggles. Sometimes, when money could not be procured anywhere, she would appeal to her father, and there is a letter in her own hand extant which proves that she knew well how to fight for her husband's cause. When after the short years of her married life she was left a widow, and everything seemed to break down around her, again it was she who did not despair, she raised up the ruins of her husband's heritage, and perserved his works to the honour of his name and of the Krupp family. This simple unpretending woman was animated by a strong will and a firm character, and it was in terms of the highest respect that Alfred Krupp spoke of his mother:—"I have learnt more from my mother than from my father, she left me the diligence, by which she saved our household". Her never-wearying industry, and the thrift that made her thoughtful of the meanest thing, she preserved until her old age, and the oldest among the pensioned workmen still remember, that in the evenings Krupp's widow used to come into the workshops, to lower the wicks of the oil lamps, so that the costly oil might not be wasted.—Until the year 1848 she remained the owner of the works, but even when her sons had grown up, she did not withdraw her former active interest in them. She died in 1850 at the age of sixty.

Friedrich Krupp had left four children, one daughter and three sons. All of them joined in the small concern, as soon as they were able to, at one time or another. Ida, the eldest of the four children, remained unmarried and like her mother devoted herself entirely to the family enterprise. As regards the acceptance of the heritage she conformed to the decision of her mother. Her share of the work during the early period of the enterprise was to attend to the correspondence. She remained at home, as long as she could be of any use to her brothers. In later years, she went to live at Bonn, where she died in 1882, 73 years old.

Of the three sons Friedrich Krupp was the youngest. Although he was undeniably talented, and did many years' work in the common undertaking, he failed in the end to become a useful and productive partner, or to fix his life's work on some definite aim. He died, the last of his brothers, at Bonn in the year 1901.

The second son, Hermann, was successfully occupied at the Cast Steel Works from 1831 till 1844. He then became a partner and co-founder of the "Berndorfer Metallwaren-Fabrik" at Berndorf in Lower Austria, where he went to reside. These works, which attained success almost earlier than the Essen works, under the management of Hermann Krupp, have also won a world-wide reputation, and by their present proprietor Arthur Krupp, Hermann's son, have been developed to a high state of prosperity.

The most remarkable among the sons of Friedrich Krupp was without any doubt the eldest boy Alfred, who was born on the 26th of April 1812. It was upon him that, after his father's death, the task devolved, in common with his mother, of setting the works going again, and of carrying them on technically at first, and soon also commercially. In 1848 the works passed into his personal possession after he had practically been at the head of them for many years. For a period of almost two generations he then conducted them as their sole head for a number of years, then assisted by his brothers, and eventually by a staff of collaborators that constantly increased as years went on, and finally assumed a fixed organisation.

Alfred Krupp's whole lifework may be divided into three clearly marked periods:— The first, from 1826 to 1848, were years of struggle against narrow means, financial difficulties, modest success, and numerous reverses and disappointments. It was the period of preparation and training, in which the foundations were laid for the eventual evolution of the works, in which Alfred Krupp's character matured, and was made fit for the work which in later years he performed in so splendid a manner, and with such brilliant success. During the second period, from 1848 to 1874, the works may be seen rising, slowly at first, then with ever-increasing rapidity, to wonderful prosperity and to the high rank which they eventually held. The year 1874, in connection with the general industrial crisis, is marked by a serious reverse, after which the third period, until Alfred Krupp's death in 1887, becomes a quiet time of formation and consolidation, during which ways were prepared for a new phase of development of the Cast Steel Works.

## YEARS OF APPRENTICESHIP.

Soon after the death of Friedrich Krupp his widow published the following notice:—

"I have the honour to announce to the valued friends of my deceased husband, that "his early death has not brought about the loss of the secret of making cast steel, for "through his foresight, it is now in possession of our eldest son, who had for some time

"already undertaken the management of the works under the guidance of his father.
"With him, I shall continue the business as the former firm of Friedrich Krupp, and
"shall endeavour to give no occasion for complaint as to the quality of the cast steel,
"or of the finished products. The following articles will be manufactured at the works:—
"Cast steel in bars of any thickness, rolled plates and forgings after drawings or models,
"such as coining-dies, stamps, spindles, shear-blades, rolls, &c. also finished tanners'
"tools. Therese Krupp."

Both she and her son, who was then fourteen years old, were encouraged to take such a decisive step, in the first place, by the faith she put in the enterprise ventured on by her deceased husband, and secondly, by the conviction that, even after his death, her own and his relatives would not desert her, and in this confidence she was not disappointed. In the commercial matters of the establishment the widow was assisted by her brother-in-law, Carl Schulz, a faithful friend of the house, and an excellent business man besides. Major Friedrich von Müller also, her husband's brother-in-law, who lived at Essen, and had faithfully stood by him for many years, did not withdraw his help now from his widow and her children. Mrs. Krupp's father and her mother-in-law too, who were the chief creditors, were indulgent in enforcing their claims, and even continued to lend her further sums in a small way. As regards the technical side of the enterprise, there was still a small body of faithful workmen left, of long experience in the works, and ready to join them again at any moment. They were seven in number, whom Alfred Krupp, in his old age, honourably named on some occasion, as his first help-mates in times of distress. There were the two smiths connected with the works for many years, Küpper and Marre, the founders Paus, Nothmann and Grabruch, finally Lautermann, who for four years had been making crucibles, and the faithful old factotum, Wilm in der Wiese, who had joined almost from the very beginning.

The first consideration now was to set things going, and to revive the relations between the works and the customers, a task which devolved upon Alfred Krupp, in spite of his youth. Having been taken away from school at Easter 1826, where he had reached the third form from below, he had during the lifetime of his father passed through a sort of apprenticeship, both at the works and in the office. When he was only thirteen and a half years old, his father had sent him in his stead to answer to a summons in court. He had also charged him with responsible transactions between himself and his customers. This early training did him very good service now. In the commercial work, he found in his grandfather Wilhelmi and in his uncle Schulz, the father of one of the partners and founders of the well known plate-rolling mills Schulz-Knaudt at Essen, examples on which he could shape himself, so that he soon became an able correspondent and business manager; in spite of his youth, the friends of the firm did not hesitate to recognise him as such. The Mint Assayer Noelle at Düsseldorf, who had remained faithful to Friedrich Krupp till to the end, headed his first letter to him after the father's death:—"To Mr. Alfried Krupp." He then goes on to discuss the continuation of the current transactions in a way which shows that he had full confidence in the professional knowledge and reliability of the fourteen years' old boy. And in fact, at once after the death of Friedrich Krupp a revival of business may be noticed. After a long pause iron was again bought for the first time, and before a year was over some fairly important finished orders were sent out. It was Alfred Krupp's first care to satisfy those customers who had remained, by a rapid execution of the orders that had been left unfinished. He then began to undertake journeys on foot through the county of the Mark, in order to add to their small number. The reputation which Friedrich Krupp's cast steel had acquired, had not altogether vanished, even official customers recognised that Krupp had supplied very good cast steel, and that it was with regret only that they had returned to steel of English make during the last years, when the works had come to a standstill, Alfred Krupp knew very well how to utilise this remnant of approbation and attachment to the firm. He was far more adroit than his father in his dealings with the customers, wherever he could, he tried to form a personal acquaintance, and he was soon known in all parts of the valleys of the Ruhr and in "the Mark where forges blaze". He visited the forges and works along the "Enneper Strasse" in the neighbourhoods of Hagen and Iserlohn, of Solingen, Remscheid and Lüdenscheid. He exchanged opinions with the people, he saw, heard and learnt, and soon he succeeded in enlarging the circle of his buyers. They were small orders indeed, that he brought home. And it was a great event when he had collected twenty-five Talers' worth on one day. Not all the goods delivered at this time were faultless, but even then Alfred cleverly managed to retain the good will of his customers, by frankly admitting what was wrong, explaining how it came about, and promising to improve matters in the future. He never hesitated to replace a piece if this was demanded.

At first, by far the greater part of the steel produced was sold in the shape of tool steel. Engine building, chiefly promoted by the requirements of the mining and textile industries, had latterly also sprung up in Rhineland and Westphalia. In 1819 the Gutehoffnungshütte took up the building of steam engines. Friedrich Harkort, the indefatigable promotor of industrial progress in Westphalia, had set up engineering works in the halls of the old castle near Wetter. Other new enterprises arose in numbers. Almost all the older establishments of this kind may be found among the customers of the Krupp works of those days. Their cast steel was much valued for chisels, turners' tools and drills, for stamps and dies, for instance for button factories, girders, &c. Krupp soon added a new product to these, cast-steel hammer faces, which he made for the forges of the neighbourhood. The face of the hammers in use, which were made of cast iron, quickly wore away. Krupp was the first to try to improve matters by inserting a narrow cast-steel face into a groove of the hammer head. This proved an excellent expedient, especially for forging steel, and soon became so popular that these hammer faces formed a very renumerative article. The product most steadily and frequently demanded, beside tool steel, remained for some time to come, tanners' tools. The men were well drilled in the manufacture of these, they were recognised as being of good quality, and their sale quickly rose, soon amounting to one third of the still very modest total. Even under the pressure of the continental blockade, the tanning industry and the manufacture of leather goods, subsisting as they did on native raw materials and markets, had always retained a certain amount of prosperity, and the town of Essen itself had a number of tan-yards with a great demand for tools. Alfred Krupp himself has later on called these products the first by which he earned his daily bread, and which therefore ought to be held high in esteem. These tools were even imitated by other manufacturers and sold stamped with Krupp's trade mark. This occasioned Mrs. Krupp to publish a serious warning in the "Allgemeine Politische Nachrichten" in 1827. Tanners' tools were also the first product for which the firm of Krupp undertook a guarantee, that is, it exchanged any defective article for a good one free of charge.

Krupp very soon found out that nothing strengthened the buyer's confidence more than such an absolute guarantee. He therefore gradually extended it to other products, and made this principle one of the keystones of his business. He had soon, however, to find out, what a responsibility he had taken upon himself by so doing. In 1827 a supply of pig iron happened to be of bad quality, and the cast steel made of it consequently turned out bad; Krupp was obliged to take back a number of lots, and replace them by others. He suffered severe damage, but it was a lesson to him henceforth, only to use the best and most carefully examined iron in his manufacture, regardless of cost, and this conscientiousness, to which the firm has adhered till to this day, became another foundation stone of its ultimate success. Krupp at once changed his source of supply, he began to deal with one of the oldest and best reputed forges in the county of Mark, the firm of Peter Brüninghaus, who manufactured Osemund iron from the very best pig iron of Siegerland. This business connection continued for more than twenty years and for almost the whole of this period, the iron supply of the Cast Steel Works had to be carted to Essen from this forge, which was in the neigbourhood of Lüdenscheid. Considering the state of the roads in those days, which was inconceivably bad, a curious picture arises before us of the awkward conditions under which commerce and industry had to fulfil their task from the 'twenties down to the 'forties.

Alfred Krupp soon acquired an accurate knowledge of the qualities of iron, he was inexorable in his requirements and in his tests, and excluded all bars that he found unfit for cast steel making. Over and over again did he warn Brüninghaus only to use the very best raw material for him, even if he had to pay a higher price, because the damage done by the use of bad Osemund iron was many times greater than the value of the iron. He was just as particular in the selection of good raw materials of uniform quality for the manufacture of crucibles; clay and graphite were only bought from the most reliable dealers, and just as his father had done, he endeavoured always to get his coke of approved coal from the seam called "Röttgers Bank" in the mine Sälzer & Neuack. The same strict principles were applied to the working procedures. For instance, after having obtained bad results when using the same crucible twice, Krupp made it a rule to break up every crucible after use, regardless of the high cost of its manufacture.

Among the customers, whose orders were still left standing over unfinished from the times of Friedrich Krupp, and who had been encouraged to continue their relations by Alfred's execution of the orders, were a number of Mints. Thanks must be given in particular to the Mint Assayer Noelle of Düsseldorf, the Councillor of Mints Teichmann of Limburg on the Lahn, and to the Mint Official Abresch, from Baden, who in spite of occasional disappointments, never for a moment withdrew their favour from young Alfred Krupp, and who thus helped him to overcome his early difficulties. The smaller mints unfortunately had no large orders to give, and from the Berlin Mint, which during Friedrich Krupp's life had sent several orders, none came now. Relying on a favourable opinion expressed by the employee of the Berlin Mint, Kleinstüber, Mrs. Krupp, in August 1828, applied to the Ministry of the Interior asking for orders from the Mint at Berlin and the workshops of the State. The small Cast Steel Works would have had plenty of work, if they had received none but the orders of the various State factories in Prussia. Tool steel for instance was used in the Government iron foundries, in the mail-coach building shops, in the mines, and last but not least in the Mints. The Mint of Berlin alone had a demand almost equal to the total output of the Krupp works. The Government authorities, however, gave a discouraging answer:—the Ministry of the Interior needed no cast steel or cast-steel goods, and therefore had no orders to give. In the spring of 1829 Mrs. Krupp once more applied to the Government, and at the same time to the Chief Privy Councillor of the Board of Revenue, Beuth, the well known director of the Prussian Deputation for

Trade and Commerce. This time she succeeded in obtaining an insignificant trial order from the Mint at Berlin, but unfortunately the goods not being altogether faultless, this remained the only order for the next two years. The Government shops continued, as they had hitherto done, to buy English cast steel, which, if it was not of better quality, was cheaper.

The economic policy of Prussia in those days showed tendencies which easily explain the failure of these various applications to the Government for support. The task of the State was not so much considered to be the direct furtherance of the industries of the country, as a promotion of public wealth, even if the individual branches of trade and industry should suffer. The Customs Act of 1818, which established the free import of raw materials and a moderate duty on finished products, had procured for all classes of the population the advantage of a cheap supply of English raw stuffs and products. And with the free import of pig iron, the iron industry in Prussia had developed favourably. Why should State factories forego an advantage which the law offered to the whole country?

The hopes placed on orders for dies and steel from the Mints, that would have given ample work to the factory, therefore proved futile. The Mints on the other hand encouraged Krupp to continue his experiments in the manufacture of hard-steel rolls, in which his father had been engaged for years, though without any lasting success. Neither in England nor on the Continent were such tools made of a sufficiently good quality to be efficient in rolling out gold, silver, copper, watch-spring steel, polished brass, &c. The famous English chilled cast-iron rolls were no substitute for such rolls, especially for such delicate work as the rolling out of bullion into fillets. Many mechanics also in the counties of Mark and Berg were engaged in the manufacture of such rolls, and every kind of new steel was given a trial. It was natural therefore that Alfred Krupp too became engrossed in the matter. Already in 1826 and 1827 he furnished several rough-forged steel rolls, which were finished in the workshops of the Mints. Brass factories too in the neighbourhood ordered similar pieces. But as soon as they were of any considerable thickness, they were frequently not evenly forged right through, and when hardened they often cracked. It was not till 1828 that a marked progress was made in this line, Heinrich Rocholl, the owner of a grindery for rolls, who by the way was a distant cousin of Friedrich Krupp, thought he had discovered in Krupp's steel a material particularly suited for his purpose. He promised to advertise Krupp's steel among his acquaintances, and gave Alfred Krupp many useful hints for its treatment in forging. After that, steel for stamps and rolls was no longer forged into round bars, but into bars of a square or octagonal section. In this way the core remained sound, and the rolls were less liable to crack when hardened. The consequence was a greater security henceforth in the manufacture of rolls.

This success with other similar technical progress, such as the manufacture of hammer faces, improvements in tool making, and such like, were an incitement to Alfred Krupp to try to see his hopes realized on the market also, and at length to be freed from the limited circumstances of his early struggles. The year 1829 marks the beginning of a most energetic movement to advertise and propagate the products of his works. In order to widen the market for tool steel and tanners' tools, he eagerly sought retailers; depots for sale on commission were established in many places, for instance with the old firm of Hamann & Wagenführ at Magdeburg, which helped to spread the reputation of Krupp's cast steel. Krupp also tried to increase his sale of tanners' tools by the system of hawking then largely practised. There are a considerable number of the most important firms of the iron and textile industries in the county of Mark, who have risen to importance from such beginnings. Their founders at one time went about the country as hawkers with their parcel of goods, selling with good profits the produce of home manufacture, hardware, woollen goods, &c. Also Alfred Krupp, who in this respect was more practical than his father, and was not ashamed to give his attention to trifles, had obtained good results from such retail sale of tanners' tools and tools in general. He now looked about for an able tanner, whom he could interest in such sale by hawking. A letter written to a man in the year 1829 is characteristic for the good-natured way in which the youth of seventeen dealt with his business connections. "You quite see, that to be on safe ground, we must have a man for this business on whom we can rely in every way, as regards honesty and application. We place all confidence in you, and we believe, that we are not mistaken. It is to our advantage as well yours, if you sell the goods so quickly that good returns come in with little outlay, you also earn your commission in a shorter time, and are able all the quicker to visit another part of the country, and we shall all the sooner manage to do business on a big scale." Alfred Krupp also endeavoured to improve production; working methods should become more expeditious and cheaper. He improved his forging appliances according to what he had seen in the works of experienced practicians of the neighbourhood, and also built a forging press for tanners' shaving knives as early as 1829; but it was a very simple contrivance, principally made of wood with steel cheeks, pressed against each other by means of wedges. The machine worked with very good success. We have sketches of it drawn by Krupp's own hand, showing what this first forging press of the Cast Steel Works, of more than eighty years ago, looked like. Krupp also thought of resuming the manufacture of files, chiefly in order to make use of the scrap from rolls and dies. He had these files forged by his workmen, and then sent them to be finished to Remscheid, which was the chief seat of the file industry of Berg. Krupp further endeavoured, to utilise both labour and appliances more thoroughly. He tried to introduce a certain division of labour, to make stamps, tools, &c. by lots, to do the casting of steel at more regular intervals, and so forth. At first such casting was done according to requirements, after 1830 regularly every other day.

But in the same measure as his efforts were attended by success, the insufficiency of the plant and equipment, under which already Alfred's father had laboured, was more and more felt by him. The inconvenience of former days, arising from the division of the works between two localities, and from the consequent distance between the forge and the foundry, in which the manufacture of crucibles and a hand forge had now been established, went on in the same way. The heavy hammer at the Walkmühle did not fulfil even the most moderate requirements, the water of the two ponds was used up in a few hours, when the hammer was at work; Alfred's workmen have since told the story, that he used to stand under the peartree of his garden looking longingly up stream, watching if the miller who lived there, was not going to draw his sluice gate. The hammers themselves, the heavier of which was only four hundredweight, were too light for the jobs to be done. If tool steel and coining dies could be forged at a pinch, the drop weight of the hammer was in no way big enough to forge roll-ingots weighing from twenty to thirty pounds. Alfred was still obliged to keep up the practice of having such pieces forged under the hammers of other works, which not only caused considerable expense in wages and transport, but even sometimes the steel was spoilt by the treatment of an inexperienced hand. Forging in those days, and more particularly the heating of cast steel was very delicate work, at which only very few smiths proved good hands. And yet this make-shift had to be adhered to for many pieces till the beginning to the 'fifties. A similar difficulty arose, when thin steel for delicate tools and for wire drawing had to be forged at the Walkmühle. Then again the hammers were too heavy, so Krupp was prevented, for many years, from being able to compete successfully with rolled English tool steel. Finally the scantiness of his working capital, which did not allow him to take in bigger supplies of raw materials, constituted another grave obstacle. A cart of iron meant almost a fortune, of clay and graphite only small supplies were bought from Essen firms, and if during the process a crucible happened to break, this was, as Krupp jokingly said in after years, equal to "bankruptcy".

The only way get out of all these troubles, and to beat English competition by the production of a good and cheap tool steel, seemed to be the erection of sufficiently powerful hammers and rolling mills at his own works. An application was made in 1829, with the object of purchasing the water power of the Berger mills, which Friedrich Krupp had already leased from the State about 1823, without being able to utilise them. But the negociations with the then proprietor of the mills, Count von der Recke-Vollmarstein, were not successful. Then the idea occurred to Alfred, to use steam power for his new plant instead of water power, which was inadequate at the best. This, however, was a plan the execution of which Krupp's family could not venture to undertake, after all the sacrifices that had already been made, and considering the scanty profits the works had hitherto returned. The sum total of the turnover during the years 1827 to 1829, only amounted to 7000 Talers, which was hardly sufficient to cover the working expenses. Mrs. Krupp therefore, in March 1830, resolved to address a petition to King Friedrich Wilhelm III, asking for a loan of 15,000 Talers free of interest. In this petition the plan was put forward, to work the hammers and the rolling mills by steam power, and to unite all the plant in the new building at Essen. But the authorities turned a deaf ear to this request; reply was made that, whatever slight deficiencies Krupp's cast steel had hitherto shown, they could not be amended by the proposed new installation, that State subvention had not proved the right means at all of furthering the manufacturing industry, that even the governmental cast steel factory at the Karlswerk, which had demanded such great outlay, had in the meantime come to a standstill. The motive for the rejection of the demand was formulated, "that the funds provided for industrial purposes did not permit the lending out of such a sum". Alfred Krupp was again, as heretofore, thrown on his own resources.

The evolution of the works could not in the long run be effectually checked; yet the unfavourable attitude assumed by the Government towards them, had the effect, of forcing their development into a new channel. The new plant, projected by Alfred Krupp was meant to facilitate the production in large quantities of current articles for the market, in the first place of steel for tools for the use of Mints. As Alfred Krupp failed in this object, he abandoned this plan, and resolutely took up another:—the production of high quality goods, that with a smaller market turned out higher profits. Prevented from expanding his production in quantity, he aimed at raising it in quality, and consequently in value. The result may be seen from the fact, that the output during the years 1827 to 1833 increased only by 50 per cent, whereas the value of the products rose by 125 per cent. A hundredweight of cast steel in the shape of bars was worth about 25 Talers, in the shape of coining dies three to four times as much, in the shape of rolls from five to tenfold that sum. There were other circumstances too urging him into this path. As often before, it still occurred that faultless lots of steel were spoiled by his customers in the finishing work. But Alfred Krupp never wearied in his efforts to convince his customers, that if his steel were properly treated it could compete with the best English produce. "How would I and other people otherwise be able to make such good things out of it", he wrote. In inexperienced hands the steel was likely to be spoiled, and the fault of course was then attributed to the steel. The only escape he saw from this trouble, was to furnish all his articles in a finished state. Both Krupp himself and his workmen could even in those times boast of extraordinary experience and skill in forging cast steel. The question now was, to make the best of that advantage. From 1830 therefore, finished goods gradually began to take a prominent place, and most customers soon saw that they were the better for it, although they paid higher prices.

The changes principally applied to rolls. For years Krupp had only furnished them rough-forged, the turning, hardening, grinding and polishing were done by the customers themselves. Most of the Mints had well-equipped workshops and skilled workmen but even here the treatment of cast steel caused difficulties, and many pieces cracked during the hardening process. Alfred Krupp, when visiting the Mint of Düsseldorf, had often looked on at the work of turning and hardening, and in 1829 he resolved to take this responsible work into his own hands. The wheels of the hammer having had to stop work for some considerable time in consequence of a severe frost during the following winter, he availed himself of the opportunity to prepare the necessary implements. Accustomed to be his own master, and to rely upon his own resources in emergencies, he built himself a small turning lathe and a plain grinding machine, which were erected at the Walkmühle and worked by a hand wheel. The first attempt proved a failure, the face of the rolls did not come out even and smooth in the grinding. Krupp carefully studied the faults and built a second one, which did better work. In April 1830, he sent out a notice to his customers, that henceforth he was in a position to furnish rolls, hardened and finished in polish. The first pair were an order delivered on the 26th of August to the firm of Hüseken at a place called "in der Nahmer" near Hohenlimburg. The first experiments had to be dearly paid for, many a pair cracked in the hardening process. "Had I"—so Krupp wrote in a letter accompanying the rolls—"known beforehand the difficulties connected with this work, I should not have accepted the order for 55 Talers, which means a heavy loss to me. Yet we have agreed on this price, and my only compensation and consolation must be, that you are fully satisfied with the result..... Henceforth I shall be able to furnish any kind of cast-steel roll, however big it be." This expectation indeed considerably anticipated facts. To start with, he could only handle very small rolls, a span long, but the letter after all reflects the pride of the young manufacturer, who had attained his end through his own strength. Krupp should soon find out what a large market there was for these hardened steel rolls, and how little of what was brought into the market by other manufacturers was good for use.

The guarantee, which Krupp undertook at first only for tanners' tools, he now extended to finished rolls. He had a long and wearisome road still before him, which only led him slowly to success. It took a long time yet before he was able to satisfy the demand for hardened cast-steel rolls of four to five inches in diameter, he was unable to forge them from heavy ingots, the striking force neither of his own hammer nor of those of friendly works was powerful enough, the steel remained porous in the core, and when hardened, cracked. Krupp on the other hand succeeded in making rolls of so-called natural steel, which after having their surfaces thoroughly hammered and polished could be used unhardened, they were very much in demand for many purposes. Orders for such rolls were executed for the great manufactories of silver ware, such as Peter Bruckmann of Heilbronn, Vollgold & Son at Berlin, also for Paris manufactories of renown, where these rolls were employed for the rough rolling of silver sheet. For more delicate work and for harder metals they proved inadequate. Krupp's inventive mind took up the problem and experimented to attain the required result by another road. He cast crucible steel round a core of iron bars heated to welding heat, and so to obtain a steel ingot with a tough welded-iron core. Although he applied himself to this task with the utmost perseverance, he could not arrive at any satisfactory solution. He only succeeded in producing very thin steel bars with an iron core, which he had forged into files by way of experiment. Whatever the results were, such experimental work helped largely to increase Krupp's metallurgical experience. In his further attempts he proceeded to produce bigger steel rolls as castings, so from forged crucible steel he passed on to moulded steel. He used all sorts of alloys and additions, such as pig iron, brass and copper filings, in order to make the steel more liquid and harder. With the latter object he used cast-iron moulds instead of clay moulds. The rolls so produced, it is true, could not compete with English chilled iron rolls, as regards hardness. But they were much stronger, and much more liable to take a very high polish, so that they could with advantage be used to roll silver bullion into fillets. The first rolls of this kind were delivered to the Mints at Wiesbaden and Darmstadt in the autumn of 1832; the latter of these, two years later, gave excellent testimony to the efficacy of these rolls. Also manufacturers of silver ware have now and then been provided with such cast rolls, and expressed their satisfaction with them. To roll out brass, however, they were not found hard enough. Just as Krupp, when attempting to weld iron and crucible steel into one, had anticipated by forty years the ulterior problem of making what was called compound steel, his steel rolls, cast in moulds, may be looked upon as the first instances in the world of steel castings, if one leaves out of consideration the attempts made by his father.

His constant efforts to produce cast-steel rolls of bigger size, also led to successful results in another line, by a procedure, whickewh liise became the stepping stone to very important inventions of after days. The manufacture of narrow disc-shaped rolls, made of an iron centre with a ring of welded steel fastened round them, had long been known. Such rolls were used to roll gold and silver wire into thin strips. They were also used in a similar way in many Mints. There was, however, this fault inherent in them, that they easily broke in the welding seam, or at least, that they showed a different hardness about this spot. Krupp attempts now were directed to making these rings of cast steel, however, without a welding joint. He pierced a hole through a massive piece of steel in the shape of a disc, and then forged it out into a ring on a mandrel. Such a ring of 4 to 5 inches diameter was inside and outside of a uniform quality, and could therefore be hardened more easily than a massive roll. After hardening, the ring was fastened on a strong steel axle. It was the same principle underlying these first small cast-steel rings, that later on led to the manufacture of hollow forged rifle barrels, but above all, to the invention of seamless tyres for railway wheels, which twenty years later laid the foundation of the world-wide reputation of the Krupp works. This is here one of the many instances, how Krupp in after years always returned to the experiences of his early life. The first pair of such cast-steel ringed rolls, worth a 100 Talers a pair, were sold to the Mint at Gotha, and soon afterwards also to that of Eisenach. Both expressed their full satisfaction with them. The Berlin Mint, which had a great demand for steel rolls of large diameters, also received several pairs, here too the work they did proved satisfactory, but the parsimonious Prussian administration was for the time being deterred from further orders by the high price. The Mint of Düsseldorf also for the same reason, adhered for some time to the practice of producing the rolls themselves. Want of work in the Prussian Mint about this time was another reason that stood in the way of Krupp's increasing his sale. The Mints in the South of Germany, at Mannheim, were good customers not given to haggle about prices. But for one thing they had little demand, and for another, difficulties arose for them through the unfortunate conditions of existing custom duties. The barrier of toll along the line of the Main had not been abolished, and as late at January 1833 Alfred Krupp had to enter into a long correspondence with the Prussian Customs Office at Cologne, about letting some rolls sent to him by the Mint of Baden for repairs, pass through free of duty.

Nevertheless the market for rolls constantly expanded, and the small workshop was consequently full up with work. Already in the spring of 1831, Krupp had transferred it to the foundry at Essen in order to have more control over the work at the lathe and the grinding machine. In the autumn he built a new grinding bench, which showed considerable improvements, although it still consisted of wood for the most part. It was not long, however, before heavier turning lathes were required. Nothing would of course have been easier, than to order excellent ready-made machine tools, for the machine tool manufacture was already then very flourishing, not only in England but also at Munich. But Alfred Krupp had not the means to avail himself of such advantages. On the contrary, for many years more had he to confine himself to machinery of his own make. The imperfections arising from the material of which this machinery was made, were compensated for by so many improvements in design, and devices for the correction of its weaknesses, that it became suited in every respect for the manufacture even of such delicate articles as gold and coining rolls. It is true, that Krupp exacted from his workmen the utmost diligence and conscientiousness, and he himself set them the best example in this respect. Therefore it did not take Alfred Krupp long to beat all his competitors out of the field by the paramount qualities of his cast-steel rolls, not only in respect of hardness, but also of accuracy of workmanship and purity of metal. He had applied himself with his full energy to this branch of manufacture, and success came, as it was sure to do. Many Mints, and private enterprises as well, acknowledged the perfection of Krupp's steel rolls by official and highly honourable testimony.

The end of the year 1831 and the beginning of 1832 were not unfavourable to an aspiring manufacturer. The moderate policy which Prussia followed in economical questions, relating to custom duties and manufacturing industries, had had the desired effect; and although some feeble enterprises here and there succumbed to the competition of England, the national wealth, the agricultural and manufacturing industries rose visibly, new establishments sprang up everywhere, and the first, though still modest signs began to appear of the tendency to substitute works conducted on a larger scale for the mode of production by handicraft, usual in the eighteenth century. The engineering industry developed fast, the German goldsmiths' industry, stagnant for some time, was revived, and the textile industry also, which had suffered severely under the effects of the continental blockade, showed a new and powerful upward movement. This revival of German industrial life, towards the end of the 'twenties of the last century, found its expression in numerous exhibitions. The effects of the liberal Prussian policy pursued in economical questions, did not pass unnoticed in the South of Germany. Such particularistic institutions as the tariff unions of South and of Middle Germany, put up as bulwarks against Prussian ascendancy, could not hold their own before the increasing pressure of the prevailing economic tendencies, which were making irresistibly for one common and united country. The Customs Union of Central Germany was abandoned in 1831 by the Electorate of Hessia, which was the first to join Prussia. This desertion was the signal for other states to follow the movement, which, as it were, by an inner necessity led to the economic combination of the "German Zollverein", formed in 1834. The improvements, which means of transport and communications underwent, kept pace with this revival of the industrial arts. New roads were built, and the old ones were put into a better state of repair; the more important stage-coach lines now did 75 kilometers a day instead of 45. Carts were built, to carry twice the former load, the carrier of the 'twenties and 'thirties of that century finally developed about the 'forties into the forwarding agent. Barges, towed up the Rhine by horses, rose much in favour for supplying the market trade, the fairs flourished once more, depots on commission, and forwarding agencies sprang up in numbers; in short, for a persevering and hard-working man, there were plenty of chances of finding a market for his products in all parts of the country.

Alfred Krupp did everything in his power to avail himself of the prevailing movement. In February 1832, soon after Hessia had joined the Prussian Customs Union, he set out on his first long journey. He travelled up the Rhine into the so-called "Oberland", touching at the towns of Bonn, Coblence, Wiesbaden, Frankfort-on-Maine, and thence visiting the principal districts of the gold and silver industries of Hessia and Swabia, the towns of Offenbach, Pforzheim, Stuttgart, Heilbronn and Hanau. He called on the Mints of South Germany, and renewed acquaintance with their managers who, some of them, had formerly been friends of his father. For the first time he looked about among the circles of gold and silver smiths, and saw, what an enormous demand there was for highly polished cast-steel rolls, which these people used to roll out ducat gold and refined silver in order to work them into ornaments and jewelry. He drew the goldsmiths' attention to his cast steel as a suitable material for dies and stamps used for making spoons, and gold and silverware of all kinds. He thus opened for himself a new and not unimportant market. He got an insight into the leather industry of the country along the Rhine, which inspired him with new hopes for an enlarged sale of tanners' tools. He established a depot on commission for such tools, and for tool steel at Offenbach, and another in 1833 at Frankenthal. He also tried to keep up his connection with his newly acquired customers through commercial travellers and retailers. With an unusual number of orders in his pocket, he returned home highly satisfied, and at once set to work to expand his sphere of action considerably.

The production of rolls and dies, hitherto insignificant, now rose to 50 per cent of the total output. The total receipt from the sale of rolls in 1831 rose from 640 Talers to 1630 Talers. The old plant and appliances were unable to respond to such an increase, especially the working of the machinery by hand was too expensive, the work of turning and grinding larger-sized rolls still took weeks. Old rolls, moreover that had been used before, now began to be sent to Krupp to be reground. The necessity of mechanical motion for his machinery became more and more urgent, and Alfred Krupp therefore resolved to transfer the turning shop, which he had only a year before combined with his foundry at Essen, once more to Altenessen, where he was able to use water power as a motor for his tools. It was thus that, in the autumn of 1832, the first mechanical workshop of the firm of Krupp was established there. Its appliances were extremely simple. One of the rooms of the upper story of the forge was arranged as a grinding and turning shop. From the axle of the water wheel a ropedrive went up to the shop; in order to keep up a sufficient tension of the rope, this was passed over the hollowed-out rim of the wheel of a barrow laden with stones. The smith and the carpenter did the best part of the work for the transmissions, axles and bearings. As for bearings, the shafts revolved in forged hooks; the driving ropes and belts passed over broad wooden drums. The machinery altogether was of an archaic type, and could in no way be compared to the products of English engineering of those days. Even the turning lathes were still fitted with wooden head and tail stocks, as were also the wood turners' benches. It was only by degrees that Krupp got iron stocks for his lathes, which he ordered at the Gutehoffnungshütte. When all was finished Alfred Krupp once more set out on a journey in the middle of winter, and paid a visit to the industrial districts of Berg and Mark, beginning at Elberfeld and going as far as Iserlohn and Lüdenscheid. His efforts were mainly directed this time to getting his products introduced into brass works, button manufactories, and similar establishments, where brass and German-silver sheet was rolled and pressed. On this occasion also his attention was first drawn to the manufacture of reed for the weaving industry, which henceforward assumed a certain importance. Since mechanical motion had been introduced into weaving mills, the sleys which have to keep the threads of the warp apart, had to stand a higher strain, and consequently were no longer made of wire, but of narrow steel ribbons similar to watch springs. These strips were rolled from steel wire, and the rolls required for this work demanded an extraordinary hardness of surface, for otherwise they would soon show impressions. There was therefore a very considerable demand for such reed rolls, which hitherto had been the produce of the handicraft of not over-skilled mechanics, who had made them of welded steel. Krupp now manufactured these rolls in the way described above, out of hardened seamless rings applied to an iron or steel core. He delivered his first pair of reed rolls in 1832, to the works of Philipp Böcker at Hohenlimburg, an old customer of his father's. Eventually these reed rolls became an important and remunerative article of the works.

It may further be mentioned, as a particular success of the year 1832, that for the first time the contents of four crucibles could be cast jointly into one ingot that weighed up to 150 pounds, the like of which in those days probably could not be produced at any other cast steel factory. In 1834 the contents of as many as eight crucibles could be poured together in one casting, producing an ingot weighing about four hundred pounds. Such work, of course, required a most careful control of the melting and the utmost care in the pouring out of the steel, since the slightest interruption of the even flow of the liquid steel would spoil the ingot. Alfred Krupp had, at one time, tried to pour the contents of several crucibles first into a casting ladle, but he soon returned to the old system of casting from the crucibles direct. These larger-sized ingots, like those still bigger of later years, requiring several hundreds of crucibles, by which Krupp obtained his universal reputation, and his ascendency over all cast steel works of the world, were originally called for by the requirements of the roll manufacture. Wherever tool steel only was produced, ingots cast from a few crucibles would suffice. At the Krupp works, on the contrary, the workmen became accustomed even in the early days to cast from a number of crucibles at the same time with great regularity, they therefore learnt by degrees to cast those large pure homogeneous ingots which caused so great a sensation at the exhibitions of London and Paris.

One can hardly form an adequate estimate of the amount of work that rested on Alfred's young shoulders during these years. Besides journeys and correspondence, the designing of his own machinery and appliances, the thinking out, planning and designing of various improvements of his plant, he had to attend to and control the manufacture of crucibles, the melting of the steel, the forging, the manufacture of the tanners' tools, and the turning, grinding and polishing of the rolls. He was even obliged to put his own hands to the work lest serious damage should be done. In the work of grinding and turning he personally instructed his men for many years, and the hardening of the rolls he attended to personally. This extraordinary amount of hard work was compensated and rewarded by the highly satisfactory feeling that he was prospering, that he possessed the full confidence of his customers, and that his rolls constituted a product that was superior to any in the country, and had no reason to fear comparison with the very best rolls of foreign manufacture. In fact these rolls meant for Krupp far more than a temporarily remunerative manufacture, they became so to speak the starting point and source of lasting returns. His experience as an ironmaster and designer, the reputation of his steel, his conquest, first of the German and eventually of the world's market, and the success of so many ulterior inventions and improvements, either date from this time or were influenced by it. Alfred Krupp in those years was by no means favoured by outward circumstances. All he attained he owed exclusively to his diligence and perseverance. The expectations with which he entered the year 1833, looking forward to an increase of yield from the new workshop now moved by water power, were in no way realised. Work was interrupted at the Walkmühle first by frost, and then by floods, upon which followed two long periods of drought during the next summer. In the face of all this, hardly any advantage could be derived from the newly-created installation. Also during the following winter neither hammers nor machinery could work for many weeks in consequence of frost. Yet in spite of all these adverse circumstances, the mechanical motive power of the shop had the result that the price of the rolls could be reduced by twenty to thirty per cent.

Alfred Krupp's next step was his resolve to limit his manufacture no longer to rolls only, but to take up the building of complete rolling mills. The rolls furnished, very often did not fit in the old frames of the reed makers and goldsmiths, very frequently also they got spoilt when working in such frames, and in consequence there were unjustified complaints. Many buyers too had no use for separate rolls. So Alfred Krupp put his whole energy, and all his rapidly developed talent for design into the job, and on the 20th of July 1833, he could deliver his first mill. The total transactions of this year amounted to 10 rolling mills to the value of 600 Talers, besides which single rolls were sold to the value of about 1000 Talers. The next year reversed the proportion, the output of finished rolling mills now surpassing that of detached rolls. So the manufacture of high-class finished products became ever more predominant as compared with the sale of tool steel. Another consequence attached to the manufacture of entire milling machinery was, that the working conditions gradually passed from the routine of the craftsman's shop to that of manufacturing works. Instead of single articles, whole series of mills of a similar size were now produced, and thus reductions of price could be obtained. The necessity of supplying the castings, such as the frames, toothed wheels, &c. from other works, also necessitated bigger machinery, such as lathes, boring-, milling-, and screw-cutting lathes, and new problems now arose before Alfred Krupp's talent as a designer, which he solved with the same splendid success. Gradually his machine tools were divested of their antiquated appearance of the 18th century. Both turning lathes and grinding benches erected after 1833 were entirely, or all but entirely, built of iron, of a modern practical type, and have done good service till as late as the 'fifties.

With this new machinery Krupp now needed men who could work it, so together with the quality of the produce the ability of the workmen was raised. Their number now had gone up to 11. In proportion as the difficulty and delicacy of the work augmented, the selection had to be made more and more carefully. The oldest men with whom Krupp had begun in 1826, had most of them disappeared one after the other, and among those that had joined later, only the best were fully competent. The first skilled mechanic, who had come to the works in 1829, was the locksmith Vierhaus; he had formerly been in the flourishing coffee-mill industry at Essen. He was a man distinguished by fidelity as well as by capability, and very soon was favoured with the absolute confidence of Krupp. Personally instructed by him, he was the first and for a long time the best grinder of rolls at the works, and headed the pay roll in 1833 with a weekly wage of 2 Talers 17½ Silvergroshens. Also Johann Schürmann, who joined the works in 1830, had won Alfred Krupp's confidence, who had personally given him instruction in turner's work. He stayed at the works till 1867, at last in the position of a foreman. His two sons Johann and Hermann, also rendered good service to the works. Among the most able workmen of the early times must be mentioned Makoni the founder, Hagewiesche, who composed the charge of the crucibles, and the locksmith Eckerfeld, who was engaged in the building of machine tools, and rolling mills. All these people worked for Alfred Krupp many years, and must be numbered among the best of his "old guard". The management of the small works was still exclusively vested in the hands of the members of the Krupp family. Alfred, who in these years often over-exerted himself, was only relieved in the business correspondence by his mother and his sister. From 1831 he was helped besides by his brother Hermann, who was now seventeen years old. After having gone through two years' apprenticeship at Solingen he came home and joined his mother's business.

All Alfred Krupp's efforts about this period did not result in any considerable or lasting increase of output. The yearly production of steel had risen from 3 tons to 4·5 tons; the total transactions of these last years, with an annual average of 3700 Talers, only very little exceeded the maximum total attained during the lifetime of Friedrich Krupp. It still by no means nearly corresponded to the former losses sustained, nor to the size of the old plant, and much less to the sacrifices made for its improvement during these last years, improvements which had only been possible by the help of others. The active assistance given by Alfred Krupp's uncle Carl Schulz during these hard times deserves special mention. This excellent man devoted himself to the interests of the Krupp family not only by giving them the benefit of his advice and his experience, but by acting as representative of the works when on his own business journeys and during his visits to the fairs of Frankfort and Leipsic. Although he had no considerable means of his own at his disposal he advanced them fairly large sums, to enable them to carry on the works and to buy the necessary materials and appliances. The first equipment of the mechanical workshop at the Walkmühle was chiefly provided out of money he had advanced. Mrs. Krupp's brother-in-law Friedrich von Müller, and his son, Carl Friedrich von Müller, who was Alfred Krupp's closest friend, also helped now and then during these years. The grandmother, the widow Krupp-Forsthoff, did not withdraw from her grandchildren that active charitable disposition of which she so often had given proof to her son. Mrs. Krupp's father, old Wilhelmi, had also contributed his share, in the way of advice and active help, to keep the concern above water during these sometimes very critical years. Other aid Alfred Krupp derived from the confidence that the firm now enjoyed again in the business world. He obtained credit from the firms who supplied him with raw materials, and the Prussian Mints, although they were sparing buyers, were prompt payers, and now and then advanced him sums on given orders. On pay days sometimes friends and relations of the family, for instance, from 1832, Sölling, Krupp's friend and afterwards his partner, helped with small sums. The improvement of the plant, however, by the addition of a new hammer and of rolling mills, both of which had been long felt to be a necessity, could not be made possible by such assistance. Things had even become worse of late, since the small water power at the Walkmühle was almost entirely exhausted by the workshop, so that the hammers could hardly ever work. So the establishment went on languishing under the old fundamental evil.

# THE ZOLLVEREIN.

The year 1834 marks the beginning of a period of quick and steady progress for the Cast Steel Works. Within three years the yearly sale rose first by 75, then by 77 and finally by 110 per cent, attaining a total value of 23,000 Talers in the year 1836. The growing reputation of Krupp's cast steel, no doubt, had a great share in this success, the primary cause of it, however, must be sought for in the change of the political situation. In 1833 the tariff union between Prussia, Saxony, Thuringia, Bavaria and Wurttemberg had finally been arranged, the rest of the states of Middle and South Germany followed, and a new economic future arose for German commerce when "in New Year's night 1834 the levy of customs for the first time ceased, when transport began to circulate freely throughout the German countries, when instead of the Prussian, Bavarian, Wurttemberg merchant and manufacturer, the German entrepreneur took the field" (from Lamprecht: Deutsche Geschichte).

To Krupp this event certainly did not come unexpectedly, and he was, no doubt, fully aware of its importance. Carl Schulz, Alfred's fatherly friend and adviser, had for years past been a regular visitor to the fairs of Leipsic and Frankfort-on-Maine, and had on these occasions, heard the importance and the progress of the tariff negotiations discussed. Both he and his nephew had had personal experience of the pressure of the existing state of things. It was most likely he too who advised Alfred, immediately after the ratification of the tariff union, or at least confirmed his intention, to undertake an extensive journey into the countries now united with Prussia, and by quick action to take advantage of the changed situation. Already at the beginning of February 1834, Alfred had firmly made up his mind to undertake a journey which was to extend over several months, but it was only on the 17th of March, that he had arranged everything at home, and could set out on his second journey up the Rhine towards the "Oberland", equipped with excellent samples of steel and rolls. It was, no doubt, not without certain misgivings that he left behind him the small factory which he himself had created, and which he cherished as his own flesh and blood. Besides to his mother, it was now intrusted to his brother Hermann, who only a few weeks before had reached the age of 20. But at this present juncture, when it was all-important to conquer the newly opened market, Alfred's activity was more necessary abroad than at home, and he knew that he could rely on his workmen. They were attached to him, as they had formerly been to his father, and many of them, such as Schürmann and Vierhaus, were not only industrious and loyal workers, but were also gifted with a high sense of responsibility.

Krupp travelled via Coblence and Wiesbaden to Hanau, the old home of the goldsmiths, where he already gained a number of faithful customers on his first journey. After that he went to Frankfort, it seems during the fair, and thence via Offenbach, Darmstadt, Pforzheim, Heilbronn and Stuttgart to Munich. At the beginning of May he continued his journey via Schwabach, to Nuremberg, and thence to Leipsic, Dresden, returning by Berlin. At Munich he made the acquaintance, among other persons, of the town clockmaker Mannhardt, one of the founders of the highly developed Munich machine-tool industry, who later on, became useful to him by the help he gave him in designing his own tools. He managed to gain the custom of the Bavarian Mint, which soon after procured him an order from the Mint of Greece, where two years before a Bavarian prince had ascended the throne. Krupp's visit to the Nuremberg district was particularly successful. Here the South-German fine-gold industry had its home, the leaf-gilding and the so-called "Lyons industry", that is the art of pressing gold and silver sheet on base metals, which originated from that town. The gold beaters of Nuremberg and Fuerth had never seen steel of such purity, hardness, and capacity for taking a high polish, as that which Krupp showed them, and consequently became his lasting customers. But above all, it was here, he received the first orders for an article, for which his works became famous for a long course of years, and which he himself always afterwards held in high appreciation as a proof of supreme worksmanhip, that is, tinsel rolls. These tools were used to roll extremely thin gold and silver wire, also copper and tin wire, into very thin strips, the so-called tinsel. Only rolls of the very highest polish, and of an impeccable purity of surface could render such work. The very least spot, even if it were imperceptible to the naked eye, would cause the delicate wire to adhere and consequently to break. Such tinsel rolls were usually bought from England or from Vienna, and at very high prices, up to six-hundred Florins the pair, yet without fully answering the requirements. At the same time, the demand for them was fairly considerable, and especially the old gold and silver lace works of Johann Balthasar Stieber at Nuremberg-Roth, which even then already employed hundreds of men, became good customers for tinsel rolls. At Leipsic and Dresden Krupp had but little success, whereas at Berlin, which he now visited for the first time, the results were satisfactory. Here, in the centre of the Prussian silver and German-silver industry, he was anxious to introduce, besides the rolls, his cast steel stamping dies, for instance for spoon making. The sale of this article very soon became more important than that of his coining dies. The advantage Krupp had over all his competitors lay again in the purity of his steel, which allowed him by the means of his approved hardening methods, to harden even the biggest pieces. None of his competitors could equal him in this respect, other works therefore frequently sent him engraved rolls to be hardened. Even engine builders sent him difficult pieces for the same purpose, because his experience in this line was well-known. At Berlin, Krupp entered into relations with the firm of J. Ravené Sons, among others, and particularly with one of the oldest manufacturing firms of silver articles of that place, Vollgold & Son, from whom he received remunerative orders for the next few years. Fully satisfied with the result of this journey Alfred Krupp returned home to Essen on the 9th of June. Besides other orders, he brought orders for rolls and entire rolling mills to the value of 6000 Florins.

At home, on the contrary, things were in a very bad way. Alfred's long absence had clearly shown what he was to the works. Except tanners' tools and some tool steel, hardly anything had been accomplished, a long drought, the usual drawback of summer, had forced all forges to stop work, and also prevented Brüninghaus from supplying Osemund iron. Alfred himself, who on his journey had had several attacks of illness, was laid up with inflammation of the lungs after his return home, upon which followed a lasting state of weakness, from which he began to recover only in September. This was a situation to discourage many a man, but not an Alfred Krupp. Even then he showed, that his full energy only developed when he was fighting against obstacles. Immediately after his return home, he constantly pressed Brüninghaus for iron, and very soon the works had again resumed their regular activity; among the most urgent tasks on hand was a Dutch order for coining-dies, given some months before. In a few weeks' time Alfred Krupp was able to despatch the first lot. With these dies, which were found to be of excellent quality, he secured the lasting good-will of the Dutch Mint, and at the same time the interest of its manager, who during the following winter came to Essen to see the works. After the Dutch order, Krupp set about those he had brought home from his journey, with the same energy. But his resources were insufficient to allow ot his accomplishing them with the same speed. The usual impediments were once more aggravated by a very dry summer, which brought all the wheels to a standstill. Reminders, reproaches, and even the refusal of acceptance of several rolling mills were the consequence of retarded deliveries. Amidst all these adversities, a decision that Alfred Krupp had revolved in his mind for years past, finally matured. He resolved to enlarge his workshops according to the wants of the times, to transfer them altogether to Essen, and to introduce steam as a motive power.

Steam engines were already then pretty generally in use in mining, but for manufacturing works, this motor was still rarely applied. Water wheels, horse and hand power were still used to drive the machinery in most works. Even in a manufacturing place like Berlin, the State had been obliged to offer steam engines to industrials as a present, and they had long hesitated before accepting the gift. After that, indeed, this first example had soon found imitators, and in 1837, 30 steam engines were at work in Berlin. But a thing which seemed advisable for Berlin, and perhaps for Silesia, the spoilt children of Prussian State providence, still seemed a great venture for the Rhine Province, poor as yet in industrial enterprise. So Krupp's intention by no means met with universal approval among his friends. Even the Mint Assayer Noelle, an enterprising man himself, in an official statement declared Krupp's intention to be a very hazardous and costly undertaking, and in no wise recommendable. But Alfred Krupp knew what he was about. It was for him almost a question of "to be or not to be". For such orders, as he now had on his hands—besides those from Bavaria and Holland, the Mints of Sardinia and Greece had also sent orders for coining dies—the existing plant was entirely insufficient. The turning and grinding benches were no longer able to do the work for the increased number of orders for rolls, not to speak of the water power. Krupp's last journey had fully confirmed his conviction of the many and great tasks that cast steel would be called upon to fulfil, the only question was to make industry acquainted with his products, and to accomplish the orders in due time. But it was impossible to attain this object with the limited old workshops. Adequate water power was not to be found in the neighbourhood, the other forges were also labouring against the same impediments as Krupp, and had frequently left him in the lurch. Steam power alone could rescue him from his difficulties. He did not for one moment doubt the success of the new plant. He wrote to Brüninghaus that after the erection of his new hammer driven by steam, his demand for iron would be "incomparable"; to the Director of Mints Goedeking:—the intended new plant would put him in a position "to produce enormous quantities, for the sale of which his present custom would hardly suffice". Alfred was then still under the delusion that with his twenty-horse-power steam engine, and his few furnaces, he would be able to supply the cast steel demand of the whole of Germany and much more besides.

Krupp's first care was the finding of capital for the new plant. The works had all along suffered from the want of liquid funds, and recently this trouble had been rendered more acute by the fact that for rolls delivered, a guarantee from 3 to 6 months had to be undertaken, and consequently credit to be given for the like period. Considerable sums therefore were in this way taken out of the working funds, while on the other hand the supplies of raw material increased. In this emergency Krupp's cousin Carl Friedrich von Müller, who in the meantime had gone to live at his property Burg Metternich near Weilerswist, came to his assistance in a most disinterested manner. He not only became security for the payment of the large iron supplies taken from Brüninghaus, and which went up month after month, but he also opened a credit for his cousin about the end of 1834 with the firm of Herstatt of Cologne, the first Krupp ever had. By this connection the cashing business of the numerous small bills of exchange he got from his customers in the South of Germany, was much facilitated. By an agreement of the 25th of November 1834, Friedrich von Müller finally became a sort of partner of Friedrich Krupp's widow, and placed a capital of 10,000 Talers at the disposal of the firm, to cover the expenses of the intended extension. In exchange for this advance, he was to receive, as a sleeping partner, a share of one third in the Cast Steel Works. Although the arrangement was made with Friedrich Krupp's widow, who was still proprietress of the works, it was the confidence in the capability of her sons that induced Friedrich von Müller to put in his capital. It was, no doubt, in consequence of this transaction, that, by a dccree of the court of the 9th of December 1834 the coming of age of Alfred and Hermann Krupp was prematurely pronounced—both designated as cast steel makers—for the reason that "after legal inquiry, it had been proved that the cancelling of the existing guardianship was more likely to promote their real and lasting welfare, than its continuance".

The main question having been thus settled, there remained another personal consideration, namely, Alfred Krupp's uncertain state of health. Could he believe himself entitled to risk the fortune of his relatives and of others in an enterprise, the continuation of which might perhaps prove impossible for him? To satisfy these scruples he applied to Doctor Timphaus of Buer, in whom he had great confidence, and asked him to be perfectly candid with him. In a letter to this gentleman he said:—"Still, fully confiding in the truth of your assurance, that I shall quite recover my health, and that my illness is not serious, relying further on your repeated affirmation that I should not allow myself to be diverted from any undertaking, I have now taken that first decisive step towards the new important extension of my works of which I spoke to you on a previous occasion. This undertaking, which if it comes to the worst, may, as I told you before, bring ruin on my house, will prove to be of the most beneficial consequences if you have spoken according to your conviction.—. . . . I have much work for my brain, I have a lot of thinking and practical work to do, in order to keep 50 men properly employed at the works, so that I hardly have time now to sleep even at night." The doctor, however, once more reassured and encouraged him, and Alfred, who indeed, after recovering from his last illness, began to feel stronger, now set to work energetically. In January 1835, a steam engine, costing 5000 Talers, was ordered from the Gutehoffnungshütte. It was a 20-horse power beam engine with 25 piston strokes per minute, and was erected in June. It had a huge flywheel, weighing 7540 pounds, and worked at "high pressure", by which was then understood a steam pressure of 2½ atmospheres. It was the 43rd steam engine delivered from the Sterkrade works of the Gutehoffnungshütte, and like all steam engines of those days, it suffered from serious deficiencies and a constant need of repair. However this may be, during 15 years it fulfilled the demands of the entire works. For many years afterwards, it drove the grinding plant, and during the years 1873-75, after having been fitted with the suitable improvements of the times, it once more undertook a job for a fellow engine, which was temporarily out of order. Then it was finally pensioned off, and has now found a well-deserved resting place in the German Museum at Munich, as an instructive illustration of the smallness of the commencement of the Cast Steel Works. For this steam engine and the new hammers, new buildings had to be put up, to which were annexed the "hardening room", wrapped in deep mystery, and a stamping mill, the engineering department on the other hand was put up in the free space of the foundry. Now the heirs could profit by what their father once seemed to have built far in excess of the requirements of the time. The foundry also afforded room for the crucible department, and, in its southern portion, for 12 turning and polishing benches. The plant for grinding rolls was removed to the attic story in order to withdraw it from the sight of the profane. Here was Vierhaus' private and carefully secluded kingdom, to which no uninitiated were admitted. After repeated bad experiences, Krupp had become very careful as regards secrecy, and had even tried to obtain permission to have his workmen sworn in to observe secrecy about their knowledge, this permission however was refused him by the Government. The arrangements of the hammers were the usual ones of the times, except that the camshaft was driven by the steam engine instead of a waterwheel. Three of the hammers were tail-helve hammers with quick motion, whereas the fourth, weighing 8 hundredweights, was a slow motion belly hammer; the camshaft was a huge oak tree 30 feet long and 3 to $3^1/_2$ feet in diameter, which there had been some difficulty in finding. These hammers worked without interruption until Alfred Krupp, about the beginning of the 'fifties, put up his first heavy steam hammers. The hammers at the Walkmühle, however, were now completely and definitely abandoned, after 25 years' existence.

With these new installations a decided change came about in Alfred Krupp's position as a chief and a designer. Hitherto he had not only been his own sole engineer, but, in conformity with his narrow means, had also learnt to content himself with the absolutely indispensable in respect of space and tools. Almost all his working appliances in the early days were a compromise between technical requirements and economy. Henceforth he abandoned this standpoint; he was no longer hampered in his decisions by the restriction of how to invent some makeshift, but was guided solely by considerations as to what machinery was most productive in output. The principle, which he frequently afterwards expressed, always to use the best working appliances regardless of cost, and which he had always followed respecting raw materials, he now applied to his machinery and tools. Expensive plant was erected for grinding, hardening, wheel cutting, &c. He no longer relied solely on his own experience and investigation, he now had recourse to the assistance of experts. By the permission of the Mining Administration at Essen, the junior engineer and mining-student Speer was engaged for the erection of the steam engine and the installation of the workshops. He entered the works in 1835 as the first technical engineer and assistant of Alfred Krupp. In erecting his hammers, Krupp consulted experienced people like Brüninghaus, the brothers Krämer of Quint, near Treves, and others, and secured the practical help of an experienced hammer builder from the district of the Ennepe. The equipping of the new workshops took up the whole of the year 1835, and a part of '36, the hammers were in full working order in March 1836. In the meantime the current orders went on increasing; in the output of steel, which in 1834 went up by a leap from 9000 to 28,000 pounds, the productive power of the new plant could be noticed. In 1835, 50,000 pounds were turned out, the output of rolls almost doubled, and rose to 42 per cent of the total sale. Much time and money was spent on the manufacture of the first tinsel rolls. The work proved much more difficult than Krupp had expected. Again experience had to be paid for dearly, and many a piece that failed was thrown into the scrap, before, in April 1835, the first pair of successful rolls could be sent off to Schwabach. From ingots carefully forged, large rings were made, then hardened and shrunk on an iron centre, which again was fixed on a steel axle, the surface was ground with extreme accuracy and finally polished. Years elapsed, before these tinsel rolls succeeded to Krupp's own satisfaction, but when this had been attained, they excelled anything that could be produced, and brought the works both fame and gain. Alfred Krupp looked upon this product absolutely as a standard for the productive skill of the works. Even as late as the 'seventies, when the production of rolls had long given way to other more important objects, he still looked upon these tinsel rolls as a criterium for the technical progress of his works. "This manufacture", he wrote, "requires more attention, more delicate treatment than the usual articles, it demands thought, practice and skill, and enhances progress." It was for this reason that he insisted on keeping up this branch.

In this way time brought many technical advancements. The year 1836 fully testified to the success of the new plant. The annual total of business done was doubled, and the number of workmen rose to 80, but on the other hand, the extension of the works was attended by new troubles. The new erections and their equipment had completely drained the capital put at Krupp's disposal, nay, the outlay proved far greater than the original estimate. Krupp himself put the expenses of the extensions at something near 18,000 Talers, he therefore was again in need both of building and working capital. With very vague hopes, Mrs. Krupp had once more, in February 1835, applied to the government, requesting an advance of 10,000 Talers for ten years, free of interest. She pointed out that the extension of the works had become absolutely indispensable, that the number of workmen had risen in six years from 6 to 45, that beyond all doubt the works would go on developing vigorously, if only sufficient working capital could be found. The result was the same as in all previous cases, the reasons given for the refusal were "that it was a principle which could not be deviated from, that the State could not take any part in industrial enterprises, either directly or indirectly". Krupp made another attempt to get a loan from the treasury of the Ruhr-Navigation Company, which in those days frequently advanced moneys for industrial purposes. This step also proved unsuccessful, because the securities demanded could not be given. In February and March 1836, in consequence of the urgent need of capital, which necessarily attended the great amount of work on hand, Krupp's situation became excessively critical. An attempt to sell the Walkmühle at this conjuncture likewise failed, a buyer for the property was only found in 1839. In this extreme distress Friedrich von Müller, unshaken in his confidence, again came to the rescue with another loan of 6000 Talers, in April 1836. This sum, for the immediate future at least, relieved the situation of the works. After this no attempts were made to obtain subventions or loans from the government. The plan of a long wished for rolling mill, and an intended wire-drawing mill Krupp had indeed to give up. He tried to obtain his object by approaching Brüninghaus on the subject of a sort of partnership, for he had everything that Krupp lacked; and at the same time, the need of spending ready money on the iron supply would exist no longer. The offer, however, was refused, and this was doubtless only for the good of a self-dependent development of the Cast Steel Works.

Alfred Krupp took the duties that became incumbent upon him through the extensions of the factory, the increase of the number of workmen, and the loan of capital, very seriously. Relieved from his attendance to daily details by the engagement of an engineer, and also of a bookkeeper since 1835, he had now more time to devote himself to studying commercial prospects, and with a set purpose he now tried to extend his market, aiming more directly at that of foreign countries. As the alterations in the works still in course of operation then, retained him personally at Essen, his brother Hermann, now a youth of 21, set out on his first business journey into the "Oberland", in order to keep up the connections that had been established in the South of Germany; this was in March 1835. Hermann proved quite equal to his task, he returned home not only with a number of orders in his pocket, but also enriched by valuable observations. Alfred Krupp had in the meantime applied to the Austrian and Russian Governments, for orders from the Mints there. He had made inquiries about exporting firms in German seaports, in Triest, in Turin, and had been looking out for business connections in France, Switzerland and Sweden. Thus the year 1835, if the few occasional earlier sales of coining dies to Holland and Greece are left out of consideration, marks the beginning of Krupp's business connections with foreign countries. In November 1835, Hermann set out on his second journey, which took him to the South of Germany and to Switzerland. He was gifted with a keen eye for what was essential, and turned his attention also to the products of competing works. He visited numerous factories and iron works, for instance the iron works at Sayn and those of Wasseralfingen in Wurttemberg, where chilled cast-iron rolls already were made, and communicated his observations to Alfred. He noticed that the Krupp rolls enjoyed the highest reputation everywhere, and that only their high price stood in the way of their general adoption. In the matter of tool steel, England, he had to admit, still held her old superior fame. The establishment of the German Zollverein had also opened the market of South Germany to English importation, which could besides sell cheaper, since tool steel was rolled there. Hermann Krupp visited the French Mint at Strassburg, and thus established the first connection that paved the way for the importation to France in after years. He was most successful, however, in Switzerland, in the homes of the gold and silver and watch-making industry. Here the hardness and purity of Krupp's product, and the guarantee offered, created an absolute sensation. These factories had hitherto worked with home-made steel, or with French and Viennese rolls of very inferior quality; now they were made acquainted with a produce of unexampled excellence, the very existence of which was entirely unknown in Switzerland. Many of the Geneva watchmakers and jewellers gave considerable orders, regardless of the price and without having any immediate use for the goods ordered. Several wholesale firms tried to secure the exclusive agency for Switzerland, and the whole of France; this, indeed, could not be granted, for several professional men had just drawn Alfred Krupp's attention to the possibility of developing a large sale in the circles of the silk, and gold and silver braid industry in Lyons, and more especially of the gold and silver industry in Paris. In the workshops of the Paris jewellers, he was told, thousand of rolls were working. Such a market could not possibly be handed over to the interest of others. So Hermann returned home in May 1836, with an abundance of new impressions, orders and hopes. The engagement of the clerk Moritz Thies, whose acquaintance he had made at Geneva, as the first commercial traveller, in summer 1836, was an immediate consequence of the journey, and proved to be a very lucky hit. In the following winter Thies started on his successful tour through France, Switzerland and

Bavaria, visiting after that Berlin, the North of Germany, Vienna and in 1838 Warsaw and St. Petersburg also.

In the meantime successful work had been accomplished at home. The hammers were in full swing, giving a new impetus to the production of tool steel. Now, as before, the most eager efforts, however, were turned to the improvement of coining dies and steel rolls, upon which Alfred Krupp looked as his most important articles of manufacture. By dint of practice and through the improvement of his appliances, he now succeeded in hardening massive 4 inch cast-steel rolls, and later on even of 5 and 6 in. diameters, and it rarely occurred now that one cracked in the process. By this achievement he surpassed all his competitors, and, where delicate work was concerned, he even then drove the much cheaper cast-iron rolls out of the field. For the manufacture of "doublé", for the cold rolling of steel sheet for instance, for the steel-pen and watch-spring industries, these steel rolls soon became indispensable. For the present, their high price—sometimes thousands of Talers,—proved a drawback to their sale. Only very gradually did the conviction gain ground, that a Krupp cast-steel roll was unsurpassable, not only in hardness and polish, but that it was absolutely indestructible, and therefore worth any price.

In the summer of 1836, the first lot of rolls was despatched to Switzerland, in the autumn to Lyons, Austria and Turin. The value of rolls sold in this year, already rose to 13,300 Talers, which was more than the total of transactions of any previous year, and more than a third was delivered abroad. Besides, steel was sold in various stages of finish, for hammer faces, anvils, files, springs, razors and pen knives, for the latter purpose even then to the well-known Solingen firm of Henckels, also for chisels, drills, spindles, paper knives, &c. The sale of dies, both for goldsmiths and mints also continued to be very important. The production of tanners' tools, after a 20 years' existence, reached its maximum in 1836, with a total value of 1200 Talers. It had never been very important, gradually went down again, and entirely subsided about the middle of the 'fifties. Thus the oldest branch of manufacture of the Cast Steel Works had existed for forty years.

In 1837 the total of transactions attained the sum of 32,000 Talers, that means in 4 years it had almost become tenfold, and at this level it maintained itself for the next years to come. The export trade had considerably grown and consolidated, it now amounted in value to three fifths of the total output. The first rolls were now sold to Brazil. The year before, Krupp had sold coining dies to the East Indies through the mediation of the Dutch Mint. The first rolls imported into Austria were for the Government factories, the Imperial Mint and the State Factory of weavers' reeds at Vienna. The exportation to France at first laboured under difficulties owing to the French protective duty. The custom houses would not even let the sample rolls pass that Thies had with him, they at first declared the importation of rolling mills to be positively prohibited. It afterwards became possible to import them on payment of a duty, of 10 to 15 per cent. The whole industry of the district of Berg and Mark was suffering under the pressure of the French customs legislation. If, in spite of that, Krupp was able to sell almost three-quarters of his entire production of rolls to France, it goes to prove, how indispensable his rolls and dies were for the jewellers' industry. The reason why things went at a slower pace in Germany, must be sought for in the narrowness of the general conditions, in the want of capital, and in the consequent disinclination of industrialists to buy expensive machinery. Krupp was very well aware of this. "A gold roll is never too dear", he wrote on one occasion to a customer, and far from trying to obtain a larger circle by underbidding, he preserved, in questions of price, a firm and sometimes even brusque attitude. On the other hand, he was always anxious to offer his customers the advantages of the latest improvements and progress. Krupp's views about this time are characterised by a letter which he addressed to Brüninghaus at the beginning of 1838. The latter had complained that Krupp's orders for Osemund iron were much in arrears of his former promises. Krupp answered him, that he had been obliged in consequence of the scanty working capital at his disposal, to restrict his manufacture to one single branch which was the most remunerative, besides Brüninghaus would remember that he had refused his offer of a partnership. The manufacture of tool steel at the time was not very remunerative in the face of the English competition, and could only be made to pay in the future, after the plant of the works had been sufficiently extended, and manufacture could be taken up on a larger scale. Krupp actually entertained the idea of applying to the Prussian Government for a protective duty on English cast steel. For this purpose he proposed, as he had done before, to send selected samples of his products to the Society for the Promotion of Industrial Arts, and to use the testimony of this society in support of his petition. In the meantime, he quietly pursued the course on which he had embarked. In 1835 he obtained with 67 workmen an output to the value of 11,000 Talers, in 1836 with 80 workmen, of 23,000, and in 1837 with only 55 workmen, of 32,000 Talers.

The markets of France, Belgium, Holland and Austria had been opened to Krupp within a few years. He now turned his attention to Russia and England. Sample goods sent to the Russian Mint, and an attempt to obtain an inlet into the gold and silver industry of that country through the agency of St. Petersburg firms, had proved unsuccessful. He therefore despatched his trustworthy clerk Thies to Russia in 1838, whereas he himself went on a journey of inquiry to England. He was in hopes of finding out the sources of supply of Swedish iron, which was invariably used by the English cast steel works. He had already tried in 1837 to procure this iron for himself through the renowned importing firm of Sykes & Son at Hull. They had, however, refused his order. He was therefore reduced to the hope of obtaining his object by personal endeavours in England. As on previous occasions, again this time his departure was retarded. Many things had to be arranged before he could be sure that work would be continued uninterruptedly. It is true that Hermann Krupp had, in the meantime, gained much experience; his youngest brother Friedrich was also now grown-up and helped in the business, but both of them and the few employees, were hardly capable of mastering all the work. Alfred tried to fill up what gaps there were by consolidating the organisation, and by limiting more precisely the sphere of action of each one individually, in order thus to establish a settled control and a regular working order. He also began now to intrust certain definite functions to tried older workmen, who thus actually were promoted the position of foremen without being distinguished by the rank of such. He was also anxious to confer the benefit of his own experience on those who remained behind. He left a quantity of written directions for the various kinds of work, and from his journey wrote many long letters dealing with the work going on at the factory, giving his attention even to the minutest details.

About the end of June 1838, Alfred Krupp set out on a journey, which kept him away from home until the September of the next year. His stay at Paris was protracted until November, because the market there surpassed anything that he had imagined. He saw, that if proper regard were paid to the French taste, the sale at Paris could be developed on an ever-increasing scale for years to come. The Paris jewellers' industry, working for the whole country, and for a large exportation besides, the gold and silver sheet and "doublé" factories would require hundreds,—perhaps thousands,—of rolls. "Paris", he wrote, "is a place where an experienced man would find business, year out year in, for all kinds of our produce." He decided to found, on the very first occasion, a depot at Paris, combined with a workshop of his own, to replace the fitter who had hitherto been engaged for the erection of his rolling mills. He received numerous orders, among others some from the Paris Mint. At the same time good news came from Warsaw and St. Petersburg, where Thies was at work. So everything seemed to be prospering. Late in the autumn Alfred Krupp left for England. He now acquired the English language as quickly, as he had learnt French in Paris. He succeeded in getting admittance into numerous industrial works and in gathering valuable knowledge. Besides business connections, he also won personal relations of a lasting and cordial nature. In January he received disquieting news from his brother, the latter spoke of an unexpected decline of business, of want of money, and of troubles of all sorts, and requested his speedy return. As had happened in former cases, Alfred's absence from home had again had an unfavourable influence on work at the factory. The zeal and willingness of his representatives could not replace his experienced and ever watchful eye. He promised to return home soon, and in the meantime tried to cheer up his distressed brothers.

Things at Essen were indeed in a much worse state than Alfred believed. When he returned to France in March 1839 he found business in a sadly depressed condition. Threatening clouds of internal discontent were hovering over Paris, and found a vent in political demonstrations that seriously cramped the purchasing power in general, and the jewellers' trade in particular. It was in vain that Alfred Krupp went up and down the staircases of hundreds of goldsmiths, the general discouragement prevented almost any order being given. This, however, did not stop him from continuing his efforts with iron perseverance, in order at least to recall himself to the memory of the people, and to be the first to be considered in case of future orders. Only at the Mints of Paris and Rouen were his endeavours even then met with favour. The dies that had been already ordered, and that had arrived during his absence from Paris, he now hardened himself, and they proved superior to all expectation. The first five-franc die coined 230,000 blanks, without any appreciable wear, whereas former dies had become unfit for further use after having produced 25,000 coins at the most. A large order for dies and rolls was the fruit of this success. Krupp's business in France, and afterwards in Belgium, detained him several months more. In the meantime the works had experienced another severe loss. On his way home from Russia, where he had been very successful, the commercial traveller Thies had fallen ill, and had died at Berlin on the 12th of April 1839. Alfred mourned his death sincerely. He was best in a position to appreciate the work of his clever agent, who in the few years of his activity had opened up the French, Austrian and Russian markets for the produce of the Krupp works, and he knew that his death would leave a serious gap in the small number of his collaborators. Nor was the other news he got from home of a cheerful nature. Two big orders that were in view from Berlin and St. Petersburg were withdrawn in consequence of the uncertainty of the condition of business, which here too resulted from the political situation. The orders from Germany also had largely diminished. In 1838 the total sale showed a slight decrease, and that of the following year only a very small increase. During both years more than half the output was sent abroad. In 1839 both France and Russia received far more rolls than all the German States together, although in both countries the goods had to be sold much dearer than in Germany, in consequence of the custom duties and the great expenses of forwarding.

Amidst all these worries, Alfred's courage never faltered. He returned home in September 1839, after an absence of 15 months, greatly enriched in experience and knowledge, matured as a man, a business man and engineer. In France he had gained an insight into hitherto unknown possibilities of sale in quite new industries, that seemed only to be waiting for his products. From England he took away a notion of the extent of the world's market, and of the resources of an old and fully developed industry. He brought home Swedish iron, and the famous Stourbridge clay used in English cast steel factories, and he never doubted that he, together with his brothers, would soon master the present difficulties, and would continue on the road to success, the prospect of which the last years had so promisingly held out to him.

# THE SPOON-ROLLING MILL.

The final and long-wished for rise of prosperity was for the present retarded by the general situation of economical and industrial life, in which just then a change was in operation in Germany. The times of freedom of trade and industrial enterprise were beginning to dawn. Production by handicraft was disappearing before the great number of industrial establishments springing up. The temporary crises of those years, far from checking this evolution, were in a way only the inevitable symptoms of such times of transition. The application of steam power in workshops, the introduction of railways, the progress in metallurgy, the wider market of the Zollverein, everything tended to the same development. The English importation of iron rose from 12 to 55 per cent of the German demand for pig iron. The industry in precious metal was also stirred by the same movements. Rolling mills and stamping machines mechanically moved were substituted for handicraft. The working goldsmiths, most of them, at least, no longer themselves rolled out their ducats and silver bullion, they supplied themselves with the rolled and polished metal sheet from the newly-established plating and German-silver works. The immediate consequence of these changes seemed at first sight to be disastrous for Krupp. The working goldsmiths, the best buyers of rolls at that time, sent few orders, exportation almost ceased in consequence of the critical state of business in France and Russia, and the output, which since 1837 had throughout maintained itself at the same level, now diminished. So the one important thing seemed to get in orders to fill up the gap which the death of Thies had caused, and Krupp set himself to this task with the same energy that he had at other times applied to technical improvements or to the organisation of working methods.

In March 1840, he went to Berlin to conclude a business transaction, the negociations for which had been going on for some time. Its object was an order of a new and very important kind, which, so to speak, constituted a turning-point in the evolution of the works. The firm of Vollgold & Son was about to transform their business from craftsmens' workshops into manufacturing works. Already in 1838, Krupp had made them a project and estimate of a plant comprising roughing and finishing mills and stamping presses for silver. But Vollgold had hitherto hesitated to give the order definitely, for it was a matter of some 5000 Talers, a considerable sum for those times. Alfred Krupp's personal influence now succeeded in prevailing on him, the order was given for a rolling mill with four pair of cast-steel rolls, a stamping press and a horse gear to drive a motor for the whole plant. It was by far the most considerable order that Krupp had hitherto received, and it may be easily understood that he did all he could to gain credit with the Berlin manufacturers. He succeeded in his attempt better than he could have expected. The machinery was finished about the end of 1840, and on Christmas Eve was loaded on carts to be sent to Berlin in the usual way, the load consisting of 100 hundredweights. This entire rolling plant was kept at work, later on by steam power, until 1908—that is almost for seventy years—at the Vollgold works. All the mills were worked hard and without interruption, yet in spite of this they are even to the present day in very good condition. A few rolls only have been exchanged during this long period. In 1909 the four rolling mills, some of the oldest witnesses of the products of the Cast Steel Works during their early years, were bought up by the firm and placed in the Museum of the works. The rolls are even now in such good condition that they, no doubt, could be worked for many years longer.

This success was a hint to Krupp to turn his efforts henceforth to the sale of big machines and the entire plant of rolling mills, rather than to that of small rolls. The evolution of the precious metal industry pointed moreover in the same direction. The output of the tinsel rolls manufacture was by no means proportionate to the producing capabilities of the works, the sale of small gold rolls had already passed its zenith, their high price had always restricted them to the "elite" only of the handicraft, besides their indestructibility left buyers no reason to refurnish themselves for long years to come. Alfred Krupp used to say, when people complained to him about the high price of the rolls, that they would last for ever; this promise came true now. "It is a great nuisance", so Hermann Krupp wrote from Paris in 1843, "that our rolls last so long, not one single pair, in Paris for instance, has worn out." This was a fact, the grave importance of which became more and more felt, as years went on. Also in other branches of the manufacture, wherever Krupp substituted his cast steel for iron, he invariably lengthened the duration of the various articles, whether they were rolls, axles, elements of machinery or tyres, and this to such an extent that the demand must eventually decrease, so that, so to speak, he was stopping up his own sources. But this again became an everlasting incitement to the works never to remain stationary at any phase, but constantly to enter on new domains, and to carry their cast steel to that great and finally world-embracing importance, which found its highest expression in the employment of cast steel for guns. These circumstances also contributed to the efforts that were already being made during the second half of the 'forties, to open up new branches of manufacture besides rolls and dies, and to place the use of cast steel on a wider basis.

Krupp's endeavours to procure orders for bigger mills, furthered by his increasing experience in hardening heavy rolls, were at first attended with very good success. He was fortunate in securing a number of such orders, among others also from the silver and German-silver works at Berlin, Vienna and Warsaw, for the newly founded rolling mills for 'doublé' in the Paris fashion, established at Barmen, for a rolling mill for the Mint at Vienna, and so forth. It even became necessary once more to extend the works and to increase the number of workmen. By degrees only it was recognised that this business was connected with much more risk, expense and difficulty than had been expected, as the erection of almost every order of any importance required Alfred's personal presence, sometimes on repeated occasions, so that during the years 1840 to 1843, he was rarely at Essen, and for very short periods at a time. In fact he was almost always travelling about, his journeys taking him to Berlin, Dresden, Warsaw, Silesia and Hungary, and very frequently, and often for a long time together, to Vienna. In July 1840, he left Essen with the intention of passing through Austria on his way to Italy, where he wished to seek new business openings. He, however, was detained at Vienna by unexpected events until the beginning of the following year, which, in the sequel, required his presence over and over again. This journey to Vienna was destined to end in more serious consequences to the firm than any former one. It became to Alfred the source of so many hardships, so many bitter experiences, that he afterwards used to say, that the colour of his hair had gone in Vienna, but, on the other hand, it led to important transactions, and to a connection which for long years to come was to be of the utmost consequences to the works.

Already in 1837 Krupp had furnished a few mills to the Mint of Vienna which had proved so successful that the Mint addressed him on the subject of an order for an entire new coining plant. The rolling mills existing at Vienna produced too little work, they were in constant need of repair, they were, as the managing department of the Mint expressed it, the "disgrace" of the establishment. Krupp offered to furnish a plant under any circumstances more efficient than that in use. In August he received an order to furnish a new adjusting machinery comprising 5 mills and 32 rolls, amounting to the value of 13,680 Florins, and in December another order for a big roughing-mill plant for 12,500 Florins. It is true, that the specifications contained very hard conditions, among other things a guarantee for ten years for all machinery. If Krupp had had sufficient practice with Mints, he would certainly have refused to agree to one of these stipulations, by which he was bound to produce with his adjusting mill, fillets of such even thickness that no subsequent adjusting of the coin was necessary. Now, this was a condition impossible to fulfil. The ingots which are rolled out into fillets, are invariably a little thicker at one end than at the other, however accurately the rolls work, the coin cut from the thicker end will always be slightly heavier, and will require a subsequent adjusting. Krupp did not know this then, and trusting to the assurances given him by the technical men of the Mint, that this condition of producing fillets of regular thickness by the adjusting mill could easily be fulfilled, he accepted a stipulation which could, if it were interpreted with ill feeling, cause the whole order to be rejected.—The preliminaries of this order kept Alfred Krupp almost six months in Vienna. Not before the New Year 1841 did he receive the last item of it, owing to the procrastination of the Austrian authorities. The term for the delivery of the first part of the order was already drawing nigh, but Alfred knew that the work was entrusted to Hermann's reliable hands at home, so he hurried, in January 1841, from Vienna to Berlin, in order to attend personally to the erection of the machinery that had in the meantime arrived there for Vollgold & Son. In February only he returned home to Essen full of great hopes. Beside the large order for the Mint, he brought home from Vienna a number of other considerable orders, and from Berlin the full amount of the money he had received for the big mill plant. In this city he had also made the acquaintance of the founder of the German-silver industry, Georg Henniger, and had discussed with him the plan of a joint establishment of big new German-silver works in Silesia to be driven by hydraulic power, and for which Henniger was to furnish the capital and Krupp the machinery. This plan, however, was not carried into effect, yet Krupp's acquaintance with Henniger resulted in a number of remunerative orders, and a closer connection with the German-silver works already then existing.

When Krupp at last arrived home again at Essen, the works were busy with the manufacture of the rolling mill for Vienna, which had been retarded some time by various incidents. The water supply had failed in consequence of a lasting frost, so that the steam engine had been unable to work, and work had to be suspended in the hardening shop. In spite of all this, the first parcels were sent in March, and soon after Alfred again set out for Vienna accompanied by his master fitter, who had already rendered useful services at Berlin. The business at Vienna proved difficult beyond all expectations. The friendly attitude at first adopted by the leading men of the Mint, had given place to an obviously unfavourable disposition to Krupp, evidently the consequence of intrigues set on foot against him by his Vienna competitors. All imaginable difficulties were placed in Krupp's way, workmen of the Mint attempted to spoil the new machinery by neglect of attendance, or by purposely overworking it, and only through the skill of the fitter and the watchfulness of Krupp was mischief averted. When after erection the machinery was tested, stipulations were imposed, which it was hardly possible to fulfil. There was an absolute want of willingness to oblige, the payments agreed upon were refused, an unbiassed test was intentionally postponed, and finally, when fault could no longer be found with the rolling mill, the stipulation was insisted on, requiring an absolute adjustment of the coin. It was in vain that Alfred Krupp tried to convince the inspectors, that such a postulation could not be fulfilled, and that it had been undertaken purely from ignorance of the nature of gold and silver bullion. It was to no purpose that he had the correctness of this view corroborated by the opinions of well-known professional men; it was of no avail that he went personally to Berlin to get information from the Royal Mint; the Vienna authorities insisted all the more obstinately on the stipulation, when Krupp himself admitted that he had promised too much.

In the meantime Alfred Krupp's absence was very seriously felt at the works at Essen which were thus deprived of their best worker. The stay in Vienna besides, had almost consumed the whole profits on the order, and the capital invested in the work for Vienna, made ready money scarce. The repeated extension of the establishment had compelled it to incur obligations which now became oppressive. The French market, once so flourishing, failed altogether, the German business in small rolls was no longer renumerative, in short the danger of a severe crisis was imminent, unless help came soon from a favourable solution of the Vienna transaction. In February 1842, Krupp appealed to Prince Lobkowitz, who had signed the contracts. This proved to no purpose either. Despairing of the possibility of success, and pressed by news from home of the situation of the works which was getting worse and worse, he petitioned for a personal interview with the President of the Royal Domain for Mint and Mining Matters, Baron Kübeck von Kubau. This upright man at last showed some understanding of the awkwardness of Krupp's position; more than this, he was also firmly resolved to lend him his aid. Krupp's letters to this gentleman, to whom he gave a confidential account of his distressing situation, cast a sharp light on the state of the works in those days. On the 2nd of August 1842 he wrote:—"I have to-day received news from my works, that the deficit through the losses alone which I have mentioned to Your Excellency, caused by the payments failing for the orders that were executed for the Imperial and Royal Chief Mint, now exceed 60,000 Florins, and such deficit means inevitable ruin to my works, if some part of that sum be not paid me. On the receipt of this news therefore I venture to place before Your Excellency this urgent request to consider my situation. Flourishing works would be ruined beyond redemption, if my request, that at least the amount of the one contract of the 23rd of December of 1840 be at once paid out to me, remain unheard. Should this be so, no help would remain for me, even if later on all the wishes I have expressed should be granted. I am standing at this present moment on the very brink of an abyss; only instantaneous help can be my salvation."

Through the intercession of Kübeck, 12,500 Florins, viz:—the sum involved in the second contract mentioned, the faultless execution of which order was beyond any doubt, was immediately paid. The differences with the Mint Authorities, by the way, lasted a very long time, and only were terminated in April 1843, in consequence of a personal decree of the Emperor in favour of Krupp, in consequence of a petition addressed to that Sovereign himself. The losses sustained through this order, the interest foregone, travelling expenses and others, may be estimated at more than 30,000 Florins. Ever in after life has Krupp retained a thankful remembrance of Baron von Kübeck, as the man who had helped him to his rights in those troublous days. In July 1843, Krupp at length found himself at home again at Essen. The order for the Vienna Mint, that had promised so much honour and profit, had kept him away from the works for almost three years with slight interruptions, and had brought him in return only disappointment and loss. It had brought the works almost to the verge of ruin. It is true, that the output which had gone down considerably in 1840, had almost doubled during the following year. But this increase was not attended by any profit, involving, as it did, an augmented supply of raw materials, the erection of new buildings, and a greater number of workmen; again the failing of payments, the added expenses of the journeys, and the long stay at Vienna constituted so great a charge on the business, that in 1842, ruin was at the door. In this extremity, a bank credit of 15,000 Talers, for which security was given by a mortgage on the estate of the works, and the above mentioned payments of the Vienna Mint brought momentary salvation. But the possibility of continuing the works during these years of distress was in the first and foremost place due to a gradual revival of exportation. This branch of business also had to pass through tempestuous times. The Russian business had begun very promisingly in 1838, and during the following year had become almost equal to that with France, but, when after the death of Thies journeys were no longer made to Russia, the orders quickly decreased, and almost ceased entirely in 1842. In March 1841, Krupp had once more broached the subject of establishing a branch business in Russia, a plan which had already been conceived by his father, in a letter to the Russian Ambassador at Berlin, but during the worries of the following year, such ideas had fallen into the background. The new exports to France, started in 1836, had wonderfully developed during the first years, so that in 1839 they rose to almost 30 per cent of the total production. In the same year, however, the above mentioned crisis in the economical development of France set in, which then soon spread over the whole of Europe. The French sale dropped in 1840 to an insignificant figure, and the whole exportation business sank rapidly within one year from 70 per cent to 20 per cent of the total output. This unexpected ebb in the French business induced Alfred Krupp, at once to put into execution his plan of establishing a permanent representative of his firm at Paris. He could only hope to reanimate the business by the help of a clever business man residing in France, who knew how to deal with French customers. The merchant Alexander Kallé of Paris was appointed the French representative of the Cast Steel Works, by a contract dated April 28th 1841. At the same time a depot for rolling mills and a small shop were established, in which rolls to be sold in France could get a final grinding and polish. Thus the first agency of the Krupp works abroad was established. It was of considerable importance for the development of the firm for many years. Kallé proved to be an extremely clever man of business, and in a very short time he succeeded in resuscitating the French business, so that during the following years a third of the total production was sold to France. Krupp himself put such a high value on this success that he afterwards said, "it was at Paris, through orders for cast-steel rolls for the gold and silver industries, that I practically laid the first foundations of the works, at a time when my business with Prussia was almost nil". Kallé also sent out commercial travellers to the South of France, opening up, from 1843 forward, the country about Lyons for the sale of Krupp tinsel rolls, where, in former times, only reed rolls had found a market. In 1843, besides Kallé, Hermann Krupp too was busy in France, because about that time there seemed to be a prospect of getting considerable orders for the French Mint, which was projecting new establishments. The negociations in this matter retained Hermann in Paris until the spring of 1844, but they eventually came to nought, and were only resumed in the following year. Kallé had also exerted himself to introduce Krupp's cast-steel cuirasses and rifle barrels, the manufacture of which had been started in 1843. It was, however, not his destiny to reap the fruit of his endeavours, he fell ill of typhoid fever in summer 1844, and died within a few days on the 2nd of June of that same year. Besides being bereft of a devoted business friend and of a successful collaborator, the firm of Krupp had also to bewail a consequent serious disturbance of the French business. In Kallé's place the representation of the firm was temporarily entrusted to the Paris firm of Richter & Hagdorn, the owners of which were two German merchants; they were definitively appointed representatives of France on the 1st of June 1845.

The year 1843 saw the three brothers Krupp once more together at Essen for some time united in common work. During Alfred's long absence Hermann had matured into full manhood and had proved as successful as Alfred as a manager and technician. His circumspection had largely contributed to the success with which the business managed to steer through the difficulties of those years, to which was added a fatal boiler explosion in 1842. It was also Hermann who, aided by his younger brother Friedrich, who was highly gifted in technical matters, continued the experiments bearing on a remarkable innovation, and which with Alfred's aid finally achieved splendid success, namely the rolling mill for spoons.

A goldsmith and engraver named Wiemer at Munich had during the 'thirties repeatedly ordered steel and rolls from the Cast Steel Works, and had a mill built for the manufacture of engraved metal sheet. During the summer of 1838, while Alfred was away in France, Wiemer ordered a new particularly strong rolling mill, which, as was found out afterwards, was intended to roll out silver spoons with the aid of rolls peculiarly engraved. Spoons had in former times been made by hand, and from the beginning of the 19th century, they had mostly been manufactured by the aid of presses or stamping machines. On his first journey to the south of Germany, Krupp had frequently received orders for the dies of such presses. Experiments had often been made, to bring out the pattern of spoons between rolls instead of by dies. A patent had even been granted in France for such rolls, but these mills of the older type worked so imperfectly, that they were no serious competitors of the spoon presses. The mill ordered by Wiemer was also so crude in design that it certainly could not produce any perfect work. However this may be, Hermann Krupp, no doubt, while building it, got the first notion of the process of rolling spoons. He wrote on the subject to Alfred, who was in Belgium at the time, and received an immediate answer to the effect that this process was most likely to have a great future, and that it therefore was well worth while to make a note of the construction of this mill. Quite convinced, that he would soon succeed in improving the invention by the aid of his steel, Alfred Krupp made an offer of such a spoon-rolling mill to the biggest Belgium manufactory of silver wares, the firm of Allard in Brussels. When he returned home, he looked more closely into the problem, and at once saw that the mill, as designed by Wiemer, produced much too little work. It could only manufacture a small number of patterns and could only produce work more imperfect than that of a common spoon press. It was only through the improvements it underwent by the brothers Krupp that it became the important invention which eventually almost entirely supplanted the old fashion of stamping spoons, forks, &c. by dies. The final success represented an immense amount of labour, perseverance, and experience in the treatment of cast steel, and perhaps Krupp, who for a long time had held the first place in the manufacture of hardened cast-steel rolls, was the only man who could have succeeded in this. His confidence in its value was so great that he at once made offers, not only in Belgium but also in Russia, for such rolling mills, and in the spring of 1840 he entered into an engagement with Vollgold & Son at Berlin, to supply a spoon-rolling mill. He very soon found, however, that he had too lightly estimated the difficulties of the job, he recalled his offers, in order to improve his invention first, as he said. Years had to pass before he could reach his final goal. Alfred Krupp's journeys, his worries and struggles at Vienna, the intermediate extension of the works, and financial difficulties stood in the way of the problem of the spoon mill. It was only in 1843 that the final object was attained, after many disappointments and great sacrifices of thought, labour and money. Not only the working methods, but also the shape of the rolls had undergone so many changes, that very little was left of the original design of the mill. The final shape of the spoons was no longer obtained by one passing through the mill, but by a division of labour, after two or three passages through different mills. The productive power of a complete set of spoon mills was in the end carried to one 150 dozen of spoons, or other parts of table silver plate per day; no other mode of production could possibly compete with this. The manufacture of the rolls themselves was very difficult. The design engraved on the rolls was such that, as the metal passed through, all the excess round about the pattern was cut off, so that the spoon so to speak came out finished from the last pair of rolls. The exactness of the engraving of the pattern, the shaping of the cutting edges, finally the hardening of the rolls, which had, however, to remain sufficiently durable to stand the enormous pressure, all these details were only realised after many years' experiments. The quality of the produce also had been so improved that no other process of manufacture could in the long run hold out against such competition. Whoever bought such machinery, acquired, as it were, a monopoly for the manufacture of table silver. This fact indeed very largely increased the value of the invention, but at the same time it seriously limited its market. It may easily be seen that, with a few installations of this kind, the whole world could be supplied, Krupp therefore decided from the very beginning only to sell one installation for every country to work silver, and perhaps a second one for the manufacture of German-silver table plate, but at the same time to demand a corresponding compensation for the monopoly thus granted. These circumstances naturally rendered it most difficult to conclude any business, for the capital involved was very considerable, and in particular the first transaction at this time, implying as it did a serious risk for the buyer, was very long in coming about; Krupp had at first entered into negociations with several German manufacturers, but without any result. Yet, while his brothers were still engaged in improving the spoon mill, Alfred Krupp had already taken decisive steps in Vienna, tending to turn his invention to profit on a broad basis.

In 1842 he had happened to became acquainted with members of the family of Schöller, a branch of the old Düren stock, who had gone to live in Vienna. Krupp succeeded in interesting the owner of the Vienna firm, Alexander Schöller, a very far-sighted man of great technical capacity, in his inventions. That winter a plan was formed to set up in common an establishment for the manufacture of table silver plate and German-silver sheet. An agreement under the date of May 1843, settled the mutual rights and obligations. Schöller together with his brothers, some in Vienna some at Düren, were to find the necessary capital, and to undertake the commercial management of the concern. Krupp should furnish the machinery, the equipment of the works, and undertake the technical management. A suitable site provided with hydraulic power had already been bought in the spring near Berndorf on the Triesting in the neighbourhood of Vienna, and it was hoped that the works would be able to start within a year's time. The buildings, however, took much longer than was expected; the establishment could only be set going in the spring of 1845. And again it took some considerable time, until the best alloy of German-silver had been agreed on, and the manufacture could be started without further delay. Finished table silver had indeed already been exhibited in May 1845 at the Vienna Industrial Exhibition, and had been awarded a silver medal, but they had been made at Essen.

The establishment at Berndorf was by no means attended by any particularly favourable circumstances for Krupp, he was not allowed to furnish, within the Austrian states, any other similar rolling mill, as long as the agreement stood; on the other hand he received no compensation for the invention, as he had in other cases for the sale of such a monopoly. Again the firm of Krupp was only to become partners in the establishment, from the moment their working capital in the business had attained the same figure as that put in by the Schöllers. Finally one of the most valuable workers of the Cast Steel Works was taken away from them to be handed over to the Berndorf establishment. For, since Alfred was indispensable, and Friedrich Krupp was still too young, Hermann was selected to go to Berndorf, and from September 1844 he went to Austria to remain there definitely. In spite of all this, the foundation of the Berndorf Manufacture of Metal Wares was not without important consequences for Krupp. Here for the first time was proved on a large scale, what the spoon mills were able to do, and the experience gained in the manufacture was all to the profit of subsequent orders and improvements. For Hermann Krupp the transaction meant the foundation of a secure position in life, and he devoted himself to it with his whole enthusiasm and energy; he attained success in it at a time, when Alfred Krupp had still to go on struggling hard for many years to come. Finally, during the critical period of 1843 to 1845, when regular orders were very scanty, the Cast Steel Works got well paid work through the orders for Berndorf, and had receipts of considerable sums of ready money, amounting to some 35,000 Talers. Also later on too, down to the middle of the 'fifties, fairly important orders were carried out for the Berndorf establishment. These things had all the more weight, since the market of the countries of the Zollverein during these years had been very slow, and without the aid of the sale abroad, it would have been impossible for the Cast Steel Works to keep up their existence.

The new Berndorf establishment did not, from the beginning, realise the hopes that had been placed on it. Not only did the manufacture meet with difficulties, but also the sale of the produce encountered obstacles during the first years. The works were obliged to sell their articles at very low prices at times, so as to accustom the customers to their rolled products, although they were much better than the current articles of those days manufactured by stamping presses. Regarding these times Hermann Krupp wrote in later years:—"Business people declared that they were only going to take our goods when they were obliged to do so, for otherwise they would become dependent on us, and afterwards would be unable to sell other goods of inferior quality. We have to send out commercial travellers, in order to get our wares known and so that the business people at Vienna received orders from other places for Berndorf spoons. It thus took seven years before any profits were returned." At first the establishment had even to work at a loss, and by the terms of the agreement the firm of Krupp had to bear the half in any deficit occurring. Until the end of 1848 these losses together with the interest accumulated amounted to more than 100,000 Florins. It took a very long time before a steady upward movement set in, which, however, when it came, rapidly developed into surprising properity.

After his arrangement with Schöller, Alfred Krupp began to look about for a chance of turning his invention to profit in Germany also. The hope of finding a capitalist, who would undertake the establishment of a spoon mill for himself, and who would be prepared to pay an adequate compensation for the monopoly, had gradually been abandoned. There was the hope, however, of establishing in Prussia a joint concern under similar conditions to those in Austria. In order to avoid any harm resulting to Berndorf, Krupp had planned an arrangement by which Austria was to provide the market of Italy and the Levant, while Prussia undertook the North, England and America. The firm of Krupp was to be a partner in both enterprises. This, indeed, was a scheme for the utilisation of his invention conceived on the widest possible basis.

Alfred Krupp thought he had found the right man for his purpose in the owner of some Elberfeld works for the manufacture of metal wares and cuirasses, named Wilhelm Jäger. He had become connected with this gentleman at the beginning of 1844 through a series of orders for cast-steel sheet to be worked into cuirasses, and it had occurred to Krupp that the spoon manufacture could be very well combined with Jäger's existing business. Although Jäger himself did not possess much capital, he was financially well supported by the old banking firm von der Heydt, Kersten & Sons at Elberfeld, relatives of his, and he believed that with their assistance he would be able to manage the matter. Soon, however, differences of opinions arose, especially as to the place where the works should be erected. For the sake of convenience, Jäger preferred Elberfeld, Krupp was in favour of Essen, as both building and working would be cheaper there. But the parties, in the course of their bargain also disagreed on other subjects; Krupp had reason to consider himself unfairly treated by Jäger, of whom he became still more suspicious, because at the Industrial Exhibition in Berlin in the summer of 1844, he had exhibited pattern specimens of plate which Krupp had sent him on approbation, without mentioning Krupp as the manufacturer. The latter therefore finally broke off the matter with the abruptness which was characteristic of him in cases where he believed his intentions misunderstood, or himself taken advantage of. This step, in this particular instance, had an unexpected sequel. Krupp's manner of proceeding was not only resented by Jäger, but also by the owners of the firm von der Heydt, Kersten & Sons, who bore him a lasting grudge. Krupp after this attempt did not abandon his plan of establishing a rolling mill for table plate at Essen, the machinery required for it was already being manufactured at the works, and in October 1844 he bought a piece of land, on which the making of bricks was at once begun. Yet the above mentioned difficulties connected with the starting of the Berndorf works, intervening, the erection of the Essen spoon-mill was postponed from one year to another, till at length other and more important matters entirely superseded it. In the meantime, however, the expenses incurred by the proposed foundation formed a considerable item of the liabilities of the Cast Steel Works for many years.

From following the steady current of a uniform development the Cast Steel Works had in the course of a few years drifted out into the open sea, so to speak, of great and responsible enterprises. It was through no levity, no bold daring that the old and sure foundations of manufacture were abandoned; the stress of circumstances forced Krupp to seek new paths. The lesser industry had been supplied with rolls that were almost indestructible, the craftmens' workshops were gradually disappearing before the rising industrial manufacturer on a large scale. When in addition to this the possibilities of a new market presented themselves, Krupp was forced to avail himself of it in order to procure employment for his works, which had also expanded. The spirit of progress ruling the works during this period, is marked by the invention and improvement of the spoon-rolling mill, by the manufacture of larger-sized rolls for silver and German-silver, by considerable progress in the manufacture of stamps and dies, obtained by a new process of pressing. Almost at the same time the manufacture of springs was begun, of cast-steel elements of machinery and of cast-steel implements for the mining industry, experiments besides had been made in rolling of cast-steel wire, and in 1843, the first rifle barrels had been forged. The next year is distinguished by the starting of the manufacture of cuirasses, and the offer of a cast-steel cannon to the Prussian Minister of War. This certainly was an abundance of new things for so short a period, yet all the arduous work demanded by them was not rewarded by any visible success till long after. For the present, the experiments and inventions involved a great expenditure of time and money without any immediate return. The spoon mill alone represented a large capital in the shape of many years' hard work and sacrifices with no profit on the credit side. When Krupp undertook the manufacture of the entire plant for big rolling mills, a domain was entered upon, which indeed was full of rich promise, but very uncertain for the present. The methods of the calculation of cost price and profits for bigger orders of this kind still lacked experience. Even the obtaining of orders demanded a great outlay, and in many cases, as for instance that of the orders for the Mint at Vienna, the expenses by far outbalanced the profits on the transaction. Alfred Krupp himself could not see any danger in this evolution of the works, for him the final victory, by which he understood the adoption of cast steel in many more new domains, was only a question of time, and his confidence in the future could never be shaken by any initial difficulties or failures. But when he looked at the actual returns so far obtained, he very clearly saw that a stronger financial basis would be required, if he wanted to continue on the new road. The increased need of raw materials and working plant, the outlay for half-finished and finished products, travelling expenses, the securities to be given to his banking firms, all this went far beyond the means he had to dispose of. Also new extensions of the works had become necessary if they were to be in readiness for any big orders coming in suddenly. In short the question of a considerable increase of the working capital became a vital one for the works towards the close of 1843 and the beginning of 1844.

Alfred Krupp's cousin Friedrich von Müller who resided at Burg Metternich, and who had been connected with him by ties of friendship and gratitude for long years, had been a sleeping partner in the Cast Steel Works since 1834. During the first years that followed, this partnership had proved very successful, and the fairly considerable capital that von Müller had invested was safe beyond all risk. But since 1840 the situation of the establishment had considerably changed, the steady and regular progress along beaten paths had given way to a development which went up and down by leaps and bounds, and which was attended by severe losses and great worries. Krupp's partnership in the Berndorf works increased indefinitely the floating liabilities of the Cast Steel Works, and Alfred did not believe himself entitled to expose the fortune of a friend who had so often helped him in the most unselfish way, to the incalculable hazards of the road lately entered upon. In this emergency however a new prospect opened before Alfred Krupp.

Ever since September 1843 he had received from the friend of his boyhood Friedrich Heinrich Sölling, a partner in the firm of Arnold Theodor Sölling at Essen and at Rotterdam, occasional sums as loans, which had accumulated to a considerable capital. This connection with Sölling was, in the course of the next year, transformed into a lasting partnership, with the consent of Friedrich von Müller. On the 2nd of April 1844 the latter's partnership was dissolved in an amicable way by the repurchase of the share invested by him. To offer him compensation for any profits that he might thus have foregone, he was guaranteed an indemnity in case the profits returned by the Cast Steel Works within 15 years should reach a certain sum. This did eventually happen. But Alfred Krupp by paying this indemnity, did not consider himself acquitted of all obligations towards Friedrich von Müller, to whom he remained a true and loyal friend as long as he lived. When after the 'sixties the works had risen to unexpected prosperity, Alfred Krupp very frequently gave expression to his gratitude towards his cousin, and never forgot the help and friendship that he had owed this man during the years of his terrible struggles. The relations between the residences of the two friends, the "Hügel" and the "Burg Metternich" remained very intimate and cordial. During his last illness, after he had become a widower, Friedrich von Müller was nursed in Krupp's house, and died at the Hügel, on the 20th of February 1874, surrounded by the love and veneration of Krupp and his family.

Sölling who, as has been said, was at first, so to speak, a lender of money to the Krupp works, on the 14th of August 1844 became a sleeping partner with an investment of 50,000 Talers. The agreement provided that, if Krupp should put in any further capital, Sölling should be obliged to raise his investment to the same amount, up to a maximum of 75,000 Talers. In return he was to receive a share of 25 per cent in the profits made, at the lowest a minimum interest at the rate of $4\frac{1}{2}$ per cent on his investment. He was exempted, on the other hand, from contributing to any losses that should occur.

This partnership lasted until the death of Sölling in 1859, and during the whole period he was a loyal friend and valued partner to Krupp. In many traits of character he was a strong contrast to Alfred. Being an experienced business man, with whom Krupp discussed all important matters, prudent and shrewd, preferring to go ahead cautiously, never risking too much at a time, he very often was not able to follow Krupp in his sanguine daring. He frequently opposed those continual expansions of the works, by which every profit was at once absorbed and which never permitted them to escape from financial difficulties. There were stormy altercations between the two friends, neither of whom would give up anything of his own decided opinion, but their cordial understanding was never seriously affected, and Sölling's zeal and interest for the works never relaxed. He did not limit his assistance to his financial share in the concern, but took a personal part in the business, and above all during Alfred's long absences, he was an excellent and watchful representative, anxious to promote the interests of the works wherever he could.

## ATTEMPTS ON NEW SPHERES.

Since the commercial crisis of 1839, an oppressive calm had been weighing on industrial life in Germany, the effects of which were aggravated by a failure of the crops and consequent dearth. It is true that with the introduction of railroads, and the use of coke in metallurgical processes, the iron industry had received a powerful impetus. But it was English rather than German industry, with its cheap production of iron that reaped the fruit of this. The founders of the Zollverein had rested too long on their laurels. Red-tapism stood in the way of a free development of ideas on economical questions.—In Germany it was only since 1844 that industrial life seemed to be inspired with new breath and energy. The free-trade tendencies which had been prevailing since 1818, at last gave way to the conviction that the rising German industry, at least in its beginnings, needed a certain protection. Duty on iron, which practically remained in vigour until 1865, became thenceforth an effective barrier against the over-powerful English competition, and also enabled German blast furnaces to use mineral coal instead of charcoal. The national iron and engineering industries were spurred to new efforts; the Industrial Exhibition at Berlin in the Prussian Arsenal in 1844, was the visible token of this new spirit, and reflected the standard at which technical progress had arrived in the lands of the Zollverein, to which 25 states with about 30 millions of inhabitants now belonged.

Here too for the first time we meet Alfred Krupp as an exhibitor. His firm was represented among other things, by a big gold roll, a pair of tinsel rolls, and a chime made of steel bars, which was used as the official chime for the Exhibition; finally by his latest invention, rifle barrels forged hollow and bent in the cold state. The extraordinary tenacity of the cast steel of which these barrels were made, especially, gained for Krupp universal admiration. The firm of Jäger at Elberfeld had exhibited German-silver plates, spoons, knife and fork handles, which had been rolled on Krupp mills, they created a sensation especially among the men of the profession. It was only through other persons, that Alfred Krupp heard of this, and anxious to secure his rights of priority, he communicated his process to the administrators of the exhibition, and to the Society for the Promotion of Industry. The gold medal which was awarded to him by the Jury of the Exhibition, he himself considered chiefly as given in recognition of his invention. Nevertheless this first exhibition of rolled spoons was referred to afterwards, when Krupp applied for a Prussian patent for his spoon-rolling mill, as one reason why its grant was refused.

The year 1844 marks the beginning of a new and briskly pulsating life for the Cast Steel Works. The orders for Berndorf gave lasting employment, the diversity of new products opened the most hopeful prospects, and the capital that had come in through Sölling's partnership permitted the erection of a number of new buildings, which had been long needed. Even the most modest offices were still wanting, Alfred Krupp had no room to work in undisturbed. Now a massive building was erected of three stories, to serve partly as a place for storage, partly as workshops. In the space left between the original cottage and the first foundry building a new two-storied house was built which provided for a very modest extension of the living apartments for the Krupps, and for a few offices, and a room for visitors. Alfred Krupp lived in this house until the year 1860, and on the 17th of February 1854 his son Friedrich Alfred was born there. He was now also able to perform the duties of hospitality, and to receive and lodge his business connections and agents at this house, for instance friends, who came from England and France, for in those days there was no proper inn or hotel to be found at Essen. The old foundry, also, which dated from his father's time, had become too small, as it now contained the turning and grinding shops, the crucible department, the first business offices, and latterly even Alfred Krupp's bedroom. During the year 1845, Alfred Krupp began to erect a new foundry with 14 improved furnaces. The draught for all of them was obtained by a central octagonal chimney, whereas in the old foundry each furnace had its own. This chimney which for some time to come became the far visible sign of the works, again afforded Alfred a chance of developing his most original talent for design, which was always following its own paths. Fearing that the chimney might crack through the expansions and contractions to which it was alternately exposed, and in order to prevent this, he had the side masonry put up in four separate segments, which permitted free movement. Finally also here and there the plant and appliances were completed. In all these extensions a capital of 20,000 Talers was invested. In October 1844, the Cast Steel Works could boast of 1 steam engine, 4 hammers, 15 forges, 26 turning lathes and other machine tools.

All was not done, however, after the enlargement had been finished. The management and superintendence also required amplifying. The number of workmen had in the autumn of 1844 risen to 131 and the growing number of new unskilled men required stricter control. A most valuable worker had been taken away from the Cast Steel Works, since Hermann Krupp had gone over to Berndorf in September 1844, so Alfred Krupp engaged his cousin Adalbert Ascherfeld, a skilled goldsmith, to take charge of the crucible manufacture, and of the foundry, and as commercial traveller and head of the office, the bookkeeper Gantesweiler was secured. In both cases Krupp's choice of fellow-workers proved as fortunate as usual. Ascherfeld was a solid character of the old Essen type, he had a kind heart in a rough shell. He loved working men and hated "scriveners"; he occasionally governed with a rod of iron, but never disappointed his men, when they came to ask him for advice and help. He had had no technical schooling, but was endowed with good practical sense, and was full of ardent zeal for his profession, a man who for twenty years devoted his services to the works, with unvarying loyalty and attachment. Mrs. Therese Krupp writes in a letter to Alfred in August 1845:—"You will surely have everything at home now as you like. Your room where nobody disturbs you, unless you like, and then you have got that good and faithful Adalbert at your side, whose happiness consists in making those about him contented with what he does." During the first years Gantesweiler had constantly to be away on journeys for the firm, he succeeded in re-animating the sale in South Germany, and in reviving the old relations with Russia, which had almost entirely expired. He had also been very active in introducing cast steel with success into the German engineering industry, which was then rapidly developing. He took over the commercial department of the firm from 1849, and was the first employee of the Cast Steel Works who received the right of signing by procuration.

During his absence, Alfred Krupp entrusted the management of the entire establishment to his younger brother Friedrich, in whom he had already early discovered extraordinary technical capacities, and who had also frequently shown his skill in business matters. When still very young, Friedrich had, while Alfred was away on his first journey to France and England, performed his first technical feat, by developing to a certain perfection a cast-steel chime composed of big tuning forks. A well-tuned chime of this kind was for a long time put up in the little turret of a small building, which went by the name of "belle vue". Afterwards "Fritz" took a lively part in the improvement of the spoon mill, and tried successfully to find a cheaper and at the same time perfectly safe way of hardening big rolls. In the smelting process also he introduced important improvements. He managed, for instance, to utilise by remelting the so called "salamanders", that is the solidified contents which had run out of leaking crucibles into the coke. It was further owing to him that the cast-steel scrap could be utilised for the melting process in a better way than before, causing considerable economy. He also succeeded in reducing considerably the dead head of ingots, that is their very porous upper part which is worthless, and which formerly was very big; he thus increased the utilizable weight of each ingot. Finally, to his and Ascherfeld's joint efforts, considerable improvements in the crucible manufacture were due. The crucibles were made more durable and of larger size, so that the medium sized ones now contained 45 pounds, whereas the biggest crucibles contained formerly only 40 pounds. In a letter to Sölling written at the beginning of 1846 Alfred expresses great satisfaction with the effects of the new division of labour:—"Friedrich and Adalbert, the latter of whom is in charge of the crucible department, have succeeded in giving a great reliability to the crucibles, which gave us such trouble for many years, and considering their activity, I do not doubt that many other advantages will be attained. Now that every one has his own department, instead of one man having to look after everthing, we work with so much more certainty and calmness, and some advantage or other may be found out, which was formerly overlooked, and of which nobody had any time to think." Like his brother Alfred, Friedrich was of an inventive turn of mind; he designed, for instance, an apparatus for the absorption of dust in the steel-grinding shop, certainly a rare thing for those days. Unfortunately Friedrich had not the power of concentrating his interest on things that were useful for the works, and the more success favoured him in his various attempts, the less was he able to check his love of enterprise, which caused him to abandon a thing hardly begun for another new one, and to waste a lot of time and money for numberless experiments, which were left unfinished, or were futile in their object. He had inherited from his father the trait of inconstancy which in him, however, now began to develop in an alarming way. He began to design automobile carriages and similar things for which the time was still far from ripe. He took the actual requirements of the business lightly. Over and above this, and in direct opposition to Alfred's prudent way of proceeding, he showed a tendency to carry out experiments with new things straight away on a large scale, as for instance, a new process of making steel, to which he was led perhaps by methods used at the recently founded Bochum cast steel factory of Mayer & Kühne. This process, which was chiefly based upon the use of puddled steel with an admixture of specular iron, did not succeed, for the time at least, and caused severe damage to the works. The more frequently Alfred was absent and the longer his absences lasted, the more this fickleness of Friedrich's clashed with the regular working order of the factory. Indeed things arrived at such a state, that Friedrich took more interest in his fanciful schemes, than in the prosperity of the Cast Steel Works. He began to give unpractical orders on his own responsibility, so that at last, the elder sister Ida prevailed upon Alfred to check this propensity of the younger brother, and that eventually Alfred, with the consent of his mother, had to remove Friedrich temporarily from the works, to which after 1848 he never returned.

His work being lightened by Sölling's partnership and by the engagement of several employees, Alfred Krupp had gradually gained more leisure, which he applied to devoting himself with renewed zeal to new problems. Various conversations with professional men during the course of the year 1844, and a visit of the chief inspector of mines von Dechen to the Cast Steel Works, suggested to him the idea of trying to get his cast steel introduced into the mining industry, in the way of miners' implements. The idea when put into practice proved successful. Several other members of the administrative body of the

Prussian Mines came to visit the works, foreman-miners and smiths were sent to Essen, to learn the treatment of cast steel. Alfred Krupp even drew up explicit directions for this purpose, which he sent to all mining authorities, and in January 1845, an official certificate issued by the Administration of Mines, confirmed that the yield of work with cast-steel tools was ten times that with ordinary steel tools. Krupp having been the first in the field, now of course hoped that he would be entrusted with the permanent supply of cast-steel implements for the Prussian Government Mines, and he made an application to that effect to the Supreme Authorities at Berlin, but his hopes proved vain. All he could obtain was a promise that the Prussian Chief Inspections of Mines should be recommended to make use of his cast steel. They were, however, left free to choose their own sources of supply, and it was other newly established cast steel factories, in various places, which reaped the best fruits of the experiments which Krupp had brought to success. Nevertheless the new article found a considerable sale to colleries, saltmines, quarries, &c. Some coalmines were also supplied with cast-steel rods for deep-boring tools and pumps, with portions of machinery made of cast steel. The manufacture of mining tools, which had to be of malleable and yet very hard steel, gave rise to further improvements in the qualities of cast steel. By slight changes in the composition of the charge, and in the time allowed for melting, he had gradually learnt to make steel of most varied properties, exactly suitable for certain purposes. These grades were distinguished by certain marks, such as crosses, flowers, &c. There was for instance tough pliable steel for rifle barrels and cuirasses, weldable steel used in the manufacture of dies, tools, anvils, steel for dies and rolls, the best qualities being used for spoon rolls, natural steel for tanners' tools and rolls which were not hardened, and many others.

Already in the 'thirties, when building his own machines, Krupp had found the use of cast steel for certain elements of machinery very useful, and had recommended it to his friends. When in 1843, he succeeded in forging hollow rifle barrels that could be bent and straightened again in the cold state, he sent his barrels to large engineering works as a proof of the tenacity and superior quality of his cast steel. But as long as iron and welded steel were sufficient to stand the strain demanded of them, the use of cast steel, which was much more expensive, was avoided. Constructors of machinery had, however, to change their attitude, from the 'forties onwards, when the strain demanded of machine elements became ever more severe. It is worthy of note, that one of the first cast-steel connecting rods was furnished by Krupp for an engine working at a very high strain, namely for a steam hammer. Navigation and railroads favoured the sale of cast steel for the same reason, for steamships and locomotive engines demanded greater strength of the several parts entering into their construction, than stationary engines did. So, from 1845 the Steamship Company of Pesth, and from 1847, the Austrian Lloyd took steel from Krupp. The German railroads, the length of which during the decade from 1840 to 1850 had risen from 470 to 5820 kilometers, were in technical respects at first entirely dependent on England. But this state of affairs only lasted a very short time. A new industry soon sprung up in the countries of the Zollverein with the object of providing the entire supply for the national railroads. In 1841 the locomotive-engine works of Borsig in Berlin and of Maffei in Munich were founded, and soon the engineering works of Kessler at Karlsruhe and Egestorff at Hannover-Linden took up the building of locomotive engines, as did Hartmann at Chemnitz in 1847, and Henschel at Cassel in 1848. All these works became very good customers of Krupp. German iron works began the rolling of rails of puddled steel. Wagon and carriage-building works were set up at Berlin, Nuremberg, Frankfort, Aix-la-chapelle, Cassel, and the railway companies themselves established shops for the building and repairing of engines and wagons. It was through this channel that connections were established between Krupp and the railway companies, the first among which were those of Cologne. Friedrich Sölling, a resident of that town, proved Alfred Krupp's most energetic and successful agent. The Cologne-Minden, the Bonn-Cologne and Aix-la-Chapelle-Maestrich railways were among the first companies to buy cast steel from Krupp. In particular the workshops of the Cologne-Minden railway at Paderborn and Dortmund gave considerable orders. In 1848 the Bonn-Cologne railway ordered the first connecting rods for locomotive engines at Krupp's and in the same year the Cologne-Minden railway took the first railway-car axles. These were the first cast-steel axles ever used on railways. Hitherto only iron axles had been used or the English patent axles of the Patent Shaft & Axletree Company at Birmingham, which consisted of a core of welded steel surrounded by a coating of iron bars welded together, Alfred Krupp thus became the father of cast-steel axles for railway cars, which have now obtained absolute supremacy throughout the whole world. Since 1847 Krupp had also taken up the manufacture of cast-steel springs for railway carriages, the first order was executed and delivered in March 1848, for the carriage builders Reiffert & Co. at Bockenheim near Frankfort-on-Maine. Hitherto such springs, particularly in the shape of the antiquated Adam's bow spring taken over from coach building, had been exclusively bought in England. It is due to Krupp's initiative that this branch of industry, which soon assumed large dimensions, and called into existence a number of important establishments, developed in Germany.

Even while the manufacture of cast-steel rolls had remained predominant, the rebuilding of antiquated coining installations in the Mints of several states seemed to offer favourable chances for finding employment for the works. As carly as 1843 there had been hopes for important orders in this line from the Paris and Utrecht Mints. But no order ensued from either. Early in March 1845 Krupp's attention was drawn by his Paris agent to the fact that the French Mint was now seriously considering a renovation of its workshops, and of setting up a new rolling plant. In April Alfred therefore left Berlin, where he had been detained by business for some time, for Paris. He was provided with letters of introduction from the Minister of Finance von Rother, to Baron James von Rothschild and Alexander von Humboldt, who was then in Paris on a diplomatic mission, and who, in a most disinterested way, used his friendly relations with diplomatic circles in Paris in favour of German visitors to France. Alfred Krupp had the good luck to gain the personal interest of the famous scientist, who remained his patron until his death. In spite of the good opinion French technicians held of the superiority of cast-steel rolls, much time passed before a decision was arrived at, and Krupp profited by the interval to go over to England, and from there to Utrecht, where the Mint likewise was on the point of deciding on the renovation of its machinery. So Alfred Krupp only returned home to Essen at the end of July with two considerable orders for mint-rolling mills in his pocket. The machinery was soon finished, and could be erected in the spring of 1846. Hagewiesche junior, also one of Krupp's confidential "old guard", and later on the "foreman of all foremen" won his spurs as a fitter on this occasion.

So this journey too had been attended by success. Nevertheless, Alfred Krupp's frequent absences from the works proved more and more detrimental—during the year 1846 and till the summer 1847 he scarely ever was at Essen—and Sölling freely expressed his dissatisfaction with them. He felt even more than Alfred himself, that, during his absence, things at home did not go on as they should, and that the exaggerated self-confidence of the younger brother did much harm. Sölling appreciated the large orders depending on so many journeys and so much risk, less than regular work carried on without interruption. He drew Alfred's attention to the fact that the expenditure was becoming out of all proper proportion to the profits. Alfred Krupp answered him in a facetious tone, in which however may be discovered the farsighted and intrepid business man:—"My stay at Berlin, during three months vagabondage between Spandau, Potsdam and Government offices does not go down as expenditure on the last year's balance sheet. Those were working expenses, as is the case with my trip to England in Salzmann's company. In Paris we saw the demise of one director, the retirement of another, and the final coming into office of a third. Those were no ordinary business expenses, they were expenses caused by the death and reappointment, of a Mint director. The visit to Denmark, Sweden and Norway likewise have cost much time and money, these again were no business expenses, they were business-devouring expenses, for they amounted to more than what the goods sold for." On the whole Alfred's manner of viewing things was no doubt, correct, but it seemed that, for the moment, the prudent Sölling was right. The large orders which had been accepted, again required the investment of considerable moneys, and the old calamity of shortness of liquid funds presented itself again at the doors of the works. Violent altercations ensued between Alfred, who, like his mother unshaken in confidence, wanted to invest all profits in extensions of the works, and Sölling who refused further advances, and insisted upon restricting the expenditure. But Alfred Krupp was not to be intimidated. He reminded Sölling of the new experiments in armament and in civil industries, the results of which could not be calculated. "If only a few of these experiments prove a success which at present nobody has a right to doubt, what may be said about the size of our establishment and of the funds that are invested in it, which, as they are, and without undertaking the manufacture of new articles, do not contain anything superflous?" Alfred, for the present, did not want any new extension, he said, but he must have his hands free, and shake off the most pressing liabilities with Sölling's aid. So he overcame all his friend's objections by his unbending will to gain his point. He offered Sölling a mortgage on the entire fortune of the family, but he insisted on getting the necessary money at once. "I must always be able to call in these 25,000 Talers, if the business requires them, and now the moment has come, although earlier than we thought it would." Considerable payments coming in for the French and Dutch rolling mills in April 1846, for the present relieved the critical situation. From another quarter, however, a spectre now presented itself, which Sölling's commercial instinct had already foreseen, and which now was assuming an ever more definite form. To a passing period of economical prosperity a fresh political, commercial and industrial depression set in. Gantesweiler sent dismal reports from his journeys, all spirit of enterprise seemed to have declined in Germany, Austria and Russia. Everywhere want of work and money prevailed; the failure of the crops in 1846, and the famine of the following winter aggravated the situation, and had a paralysing effect on all branches of business. Again the problem of finding new markets and new fields for his cast steel, presented itself to Krupp, if he wished to keep his works up to the height they had obtained. This time his efforts were directed more seriously than ever before to England.

When Alfred had visited England for the first time in 1839, his main object had been to gather general information on the conditions of English industry, and in particular of the cast steel manufacture. The years that followed absorbed both his and his brother's energies so completely, that there was neither time nor opportunity for any attempt to extend exportation to England. Alfred's second trip to England was in company of the Dutch director of Mints in 1843, and was devoted to the study of the Mint workshops in London, upon the result of which the renovation of the rolling-mills of Utrecht had been made contingent. Krupp had, on this occasion, become acquainted with the English chilled cast-iron rolls and the manner of their application. He saw that they were still ill-suited for very delicate work, and he had no doubt that one day he would be able to supplant them for certain purposes by his cast-steel rolls. He sought the acquaintance of the Prussian Consul General Hebeler in London, then a commercial agent for transactions between England and Germany, who had supplied railway material, for instance English rails, for the first German railroad. Hebeler also undertook the sale of Krupp rolls in England, but, owing to his already very extensive sphere of action, only small results were secured. After his third stay in England in the summer of 1845, Krupp therefore entrusted the firm of Johnson & Simpson, with the sale of his goods on commission, but neither this firm was sufficiently active to be successful in overcoming the difficulties of obtaining an English market for such goods. From this time forward, Alfred Krupp was very frequently in England. He was in London in 1846 to lodge an application for a patent on his spoon mill. The patent was granted on August 26th 1846, on condition that, within six months, a detailed description with drawings of his invention should be placed before the English Patent Office. On this occasion he tried to find a market for his tinsel and gold rolls, but with very modest success indeed, sufficient, however, to induce him to undertake a second journey to England towards the end of that year. Besides a number of orders for tinsel rolls, he now received the first for big hardened rolls for the manufacture of steel sheet for pens. By this at length the reputation of Krupp's cast steel, and the products made from it, became definitely established in England. Among professional men the rolls excited so much interest, that even the manager of the London Mint declared himself ready and willing to accompany Alfred Krupp to Birmingham in order to see them work. When, in the course of years, the rolls had proved almost indestructible, the hitherto prevailing belief in the superiority of chilled cast-iron rolls was seriously shaken, and henceforth, in England Krupp's cast-steel rolls were also preferred for fine or delicate work. The main object of this journey, however, had been the foundation of works in England for the manufacture of plate and plated goods, but in spite of many months exertions in London and Birmingham, this could not be realised. The general depression of trade had also affected English industry. The discount of the Bank of England was higher than it had ever been since the days of Napoleon. So Krupp's hopes were disappointed for the time. But they were realised in 1851, in a most splendid and unexpected manner. In the meantime he sent in to the English Patent-Office the required drawings and description of his spoon-rolling mill, and at the same time made applications, referring to the English patent, to the authorities in Prussia, France, Belgium and Russia, asking for the same protection of his invention, as he had been granted by the English patent, for a period of fourteen years. All the states granted the patent except Prussia, where it was alleged that the essential object of Krupp's patent was already known, that it had been applied, although in a different combination and in a different form. Alfred Krupp made a second application, protesting that it was an undeniable fact that all former attempts to roll spoons had remained without any practical result, and that the exhibition of such goods at Berlin, in 1844, and at Vienna, in 1845, only resulted from productions of his own machinery. The Prussian authorities, however, abode by their refusal, which Alfred Krupp resented all the more, because he thought that in his own country he might expect, in the first place, to find that protection which no foreign government had refused him.

Krupp returned home in the summer of 1847 disappointed in many of the hopes with which he had set out. On the way, it is true, he had been able to interest a spoon manufacturer, M. Bonnevie of Brussels, who for some years had been using Krupp's cast steel for stamps, in his spoon-rolling mill. Bonnevie came to Essen himself, and for him, as a professional man, it was the same thing "to see the operation, and to be firmly convinced that the old method could not prevail against it". Bonnevie gave an insignificant order, but he could not be brought to consider the purchase of the Belgian patent; yet it was a step forward, to see the invention adopted in a well-known Belgian establishment and to be able to furnish there to French and English possible purchasers the proof of their productive power.

The sale at home, as was usually the case during Alfred's long absences, had again diminished. It is true that active work had continued, that technical progress had been obtained, that the reputation of the Cast Steel Works had risen, and that men of rank had come to visit the works. Professor Schubarth, who had come to see the works in 1847, by order of a Prussian committee for the superintendence of industrial works,was shown the mechanical workshop, rolls in course of manufacture, a few large ingots, some of which already then weighed ten hundredweights; he also saw the gun tube of the three-pounder, that afterwards became so famous, and which was sent to Berlin as the first of its kind; he also inspected steel cuirasses, rifle barrels and finished forks and spoons, the manufacture of these, however, he was not permitted to see. Yet after all, the establishment had yielded no profits during these bad times. The total of transactions, which in 1846, owing to the Dutch and French orders, had risen to 80,000 Talers, in 1847 went down again to little more than the half of that. The balance sheet of the 31st of December 1847, for the first time after many years, again showed a considerable deficit, which Krupp had to bear alone, as Sölling by the terms of the contract, only shared the profits. Krupp's hopes of forcing the sale of his new products had so far not been realised. The only produce, the sale of which went up, was tool steel, a proof that Krupp's cast steel was now universally used in the engineering industry. Otherwise, it was during this year and the following critical years, chiefly the foreign market that consumed the greater part of the production, only that the exportation was now more evenly divided between the several countries. Besides to France and Austria, considerable orders now also went to Russia, Belgium, Holland, and of late years also to England. Beyond doubt, the depressing results of the later years were chiefly due to the economical conditions of the time, but in some way they must also be attributed to internal circumstances. In the composition, and consequently in the properties of Krupp's steel, the old evenness and reliability were no longer to be found. Perhaps Ascherfeld had not yet gained sufficient experience, and his good intentions were frequently frustrated by the arbitrary orders given by Friedrich Krupp. Even Hermann Krupp wrote, warning his brother, and expressing his disapproval of the last steel supplies he had received. In after times recollecting those days, Alfred wrote about his brother Friedrich:—"My brother, formerly a very diligent and loyal worker, was led away to become overbearing, he took no notice of me, thought himself a prodigy . . . . . although there was plenty of work, fortune forsook the business." In spite of this, he treated his brother with excessive indulgence so that the sister Ida, who then lived with her mother at Bonn wrote to him, urging him to be more severe with Fritz.

So the New Year of 1848 did not open with bright prospects for the works. Once more everything that Alfred's father had founded amid so many hardships and disappointments, and had finally paid for with his life, that Alfred himself, in twenty-one years of hard and unintermittent work had developed into modest prosperity, seemed on the brink of ruin. These sorrows and cares were a heavy burden to the family and to the friends, among these above all to Sölling, then to Friedrich von Müller at Metternich, and to Carl Schulz at Essen, who all took a sympathising interest in the success of the works. It was Schulz who, in February 1848, was struck with an idea, which relieved the difficulty. He advised Alfred's mother, who was still the sole proprietress of the works, to exclude her youngest son entirely, and to transfer the works by sale to Alfred. A uniform and energetic management now seemed the only means of releasing the works from their present difficulties. It was probably, too, the only way to induce Sölling to remain a partner. It is most probable that Mrs. Therese Krupp could only be persuaded to take the step very reluctantly, because her heart was equally devoted to all her children, but her practical common sense told her that it was the only wise course. Ida and Hermann also gave their consent, so did Alfred, perhaps not without serious misgivings, for he knew best what a burden he was taking upon himself in the present state of things. By a deed of purchase dated February 24th 1848, the works with all their assets and liabilities passed to Alfred Krupp as sole proprietor for the sum of 40,000 Talers; it was extremely difficult for Friedrich Krupp to acquiesce in this new state of things, but he too gave his consent, and agreed to abstain from taking any steps to the detriment of the establishment, and particularly from founding any similar works in partnership with others. Considering his inconstant nature, and his tendency to contradiction and revolt it may not have been easy for him to keep his promise. After several failures to set up in business for himself, he finally gave up the attempt, and went to reside permanently at Bonn, where his sister Ida lived. To the last, Alfred showed him a brotherly and friendly affection, and enabled him to lead a life free from care, free to follow his own inclinations. Friedrich long outlived all his brothers and sister, he only died in 1901 at Bonn, having attained the age of eighty years.

Immediately after the above contract had been made, events occurred that made a reduction of the purchasing price necessary. The balance sheet of the Berndorf works, which had been expected to present considerable profits, on the contrary showed a deficit of more than 30,000 Florins, half of which was to the debit of the Cast Steel Works. A little later the March revolution broke out, which shook to the foundations the already vacillating commercial and industrial life of Germany. Many works closed their gates, the rest reduced the number of their workmen. In the face of such a state of things the purchase money was reduced to 25,000 Talers, by a second contract of the 29th of March 1848. This transaction also gave rise to a complete separation of the Berndorf works from the Essen works, the latter paying out to the former the total of the deficits so far sustained, and transferring the right of ownership to Hermann Krupp. This was a great gain to both parties, Friedrich Sölling had always considered this union with Schoeller as a clog on the Cast Steel Works, and had advised Alfred, to get rid of it as soon as possible. Nor had this partnership any attraction for Alfred, being now merely of a financial nature and allowing him no scope for personal activity. Hermann, on the other hand, who had now had the entire technical management at Berndorf for the last four years, found his position considerably strengthened by Krupp's share in the deficits being paid off. This unfavourable balance sheet of 1848 was for the Berndorf works, so to speak, the last chapter of the difficulties of their commencement. The production increased, and the profits went up so quickly that Hermann Krupp, who since 1850 had become a recognised partner, was enabled till 1860 to raise his share of the capital to the same figure as that of the members of the Schöller family.

So Alfred Krupp had now at last become the real proprietor and sole manager of the works to which he had for twenty-one years devoted every single day and every single thought. He took them on at a moment when the burden of the present and anxiety for the future weighed more heavily on the enterprise than they had done for years. The first task before him was to steer the works through the troublous times of the year 1848. The first sign of the coming storm showed itself in Paris. Alfred withdrew his depot in April, in order to save it from destruction by the mob, and the French agency was cancelled for the time being. It was most difficult to keep sufficient work going at the factory. Orders became fewer and fewer, large orders did not come in at all, so universally was the confidence in the times shaken among business men. Orders therefore of 1200 dies for the Dutch Mints, to harden which a foreman had to be sent to Utrecht, 25 railway carriage springs for Reiffert & Co. at Oppenheim, a few minor orders for the Royal Mint at Berlin, a pair of rolls for the Swedish Mint, trifles compared with the business done during the last few years, were now hailed with joy. The transactions from January to June 1848, amounted to less than half of those in the same period in 1847, Alfred left nothing untried to keep up the staff of workmen without any further reductions. The report of the Chamber of Commerce at Essen of 1848 says:—"Considering the situation, the Cast Steel Works near Essen were in the most difficult position of any of the industrial establishments, and it must be mentioned that the work there was continued in the same way as before."

None of the really useful men were dismissed during the March troubles. The workmen were kept on at the works, even though there was no employment for them, in order to keep them from idling about and joining the tumults in the streets. Alfred reminded them of the traditional bond existing between the family and the employees and warned them against listening to the agitators. "It is all very well for them," he said, "to talk grandly, but just go and see what life those people lead in their homes." As a matter of fact, not one of Krupp's workmen took any part in the street riots that occurred at Essen. When a state of siege was declared in the town they marched in a column headed by Ascherfeld, into the town and were let in through the gate, which otherwise was kept locked. Wages continued to be paid just as if everything was going on as usual; it was a great sacrifice which Alfred Krupp made, but it was one for the welfare of his workmen and the future of the works. It was indeed a difficult task to provide for 70 workmen, when no money was earned, and capital, especially from the banking firms, was difficult to have. An old and highly respected banker at Cologne, Abraham Schaaffhausen stopped payment in March, and was only saved by his bank being transformed into a joint stock company the "A. Schaaffhausen'scher Bankverein". The bankers Herstatt and Sölling also seem to have deserted Krupp in these days, and he was reduced sometimes to borrow the money for pay days from acquaintances in small sums and at high interest. Now the value of a spotless reputation, acquired throughout twenty years of work and honest dealing, was fully appreciated. Once when all his resources seemed exhausted Krupp took a last desperate step. In one of the upper rooms, behind the hardening shop of the three-storied house, which still exists in the middle of the works, as a remnant of the first establishment, he had all the silver of the family molten down by the foreman of the hardening shop, Borgmann, who was reliable and discreet. On the 26th of April 1848, on Alfred Krupp's 36th birthday, Ascherfeld took the ingot to be sold to the Düsseldorf Mint, so as to be able to pay the workmen's wages. For a long time that room, probably in consequence of this incident, was called the silver chamber. Twenty-eight years later Alfred Krupp himself related this event: — "No money was to be had on bills of exchange, then I had spoons, jugs, spurs, medals, molten down, and, as by a miracle after that day, I had plenty of work and plenty of money."

The "miracle" alluded to was a remunerative order for spoon rolls, which at length came in the month of May, and gave employment to the works for the second half of the year. After his failure in England, Krupp had endeavoured to promote the foundation of spoon-rolling mills in France, Spain and Poland, even in North and South America. But the times were so unsuitable that he was not successful. A transaction which had been under consideration for more than a year, was now at length decided; the Duke of Leuchtenberg at Warsaw, a grandson of the first empress of the French, Josephine Beauharnais, had seen the spoon-rolling mill at Paris and had manifested an interest in founding works of the kind in Russia. The result was the order given in May 1848, for which the Duke declared his willingness to pay a first instalment of 9000 Rubles, in July. Considering the times, this meant salvation to the Essen works. The entire machinery, to the value of 21,400 Rubles, was delivered before October. In the autumn a second, but much smaller order, for spoon rolls was given by Jürst's German-silver works in Berlin. These two orders making up together 60 per cent of the total of the year's transactions, one may imagine what their importance was for the maintenance of the works. We may say with truth that it was the invention of the spoon-rolling mill which enabled the Cast Steel Works to keep above water during those critical years. The fact still remains, however, that all these orders, with a few subsequent ones for works manufacturing table plate in Berlin, Paris, and Warsaw were not remunerative enough to signify a realisation of the hopes that had been placed on this invention. There is only one big and very successful transaction later on, in 1851, with the English firm of Elkington, Mason & Co. at Birmingham, and which comprised, besides the order for the machinery required, the sale of the English patent. The amount received for this sale was £ 8000, and it was for the most part invested in the building and equipment of a number of new shops, of which the works were then much in need. This event concluded the predominance of the rolling mill as a factor in the development of the Cast Steel Works. Henceforth, a new feature of modern civilisation, the railroad, claimed the interest of the works, and led Krupp's inventive mind on to new problems, the solution of which became the fundament of the next phase of the Cast Steel Works.

# 1848—1870.

Between 1848 and 1870 lies the period of the Cast Steel Works marked by their most splendid and most multiform evolution. When Alfred Krupp in 1848 took over the works as sole proprietor, they were modest in extent and even on the decline, employing only 70 workmen then, as compared with upwards of 130 a few years before. Since the first extension of the premises in 1835/36, the works had hardly grown, although their market had considerably increased. Twenty-five years later the Cast Steel Works had developed into an industrial enterprise which ranked among the biggest of its kind. The premises occupying an area of 0,5 hectare in 1848, covered an area of 35 hectares in 1873, and 12,000 workmen were employed. The establishment had besides purchased collieries, iron-ore mines, and blast furnaces, giving employment to another 4000 workmen. The number of steam hammers had risen from 4 to 71, that of the steam engines from 1 to 286.

The nature of Krupp's establishment had also undergone an essential change. In 1848 it was still engaged in the manufacture of specialities, and although moderate in size, its reputation was well established. Cast steel had not, in 1848, succeeded in gaining a universal application, rolls and rolling mills still formed the main article of produce, constituting on an average 4/5 of the total output during the last decade. This average during the 'forties amounted to the yearly receipt of 40,000 to 50,000 Talers, but oscillated between sums much lower on one hand and very much higher on the other, attaining in one year 80,000 Talers. It must be remembered that the foundations for great future developments had already been laid before 1848, the manufacture of parts for the engineering industry, and of railway material had been started, and the first gun tube had been made. Looking at the works at the beginning of the 'seventies, we find a gigantic expansion in size, the spheres of application of cast steel have multiplied in all the branches alluded to above, besides which the manufacture of gun tubes had been completed by the making of their mounts and carriages, and the necessary ammunition. Again, through the adoption of the Bessemer and the open-hearth steel processes, and through the acquisition of blast furnaces, iron-ore mines and collieries, the works had been transformed into large and important iron works and rolling mills. In consequence of this diversity of activity, the further evolution of the establishment can no longer be continued along one single line, for henceforth not only the existing lines had to be followed up, but also quite new departures had to be made, which widened and modified the form and nature of the works. It will, therefore, not do to trace out their evolution on the method hitherto applied. The further description must necessarily be divided into a series of monographs, the underlying connection between which, however, is elucidated by the short prefatory survey which follows.

The development of the works, down to the end of the 'fifties, is essentially determined by cast steel gaining ever more ground in the engineering, railway and ship-building industries. The consequence was that the crucible-steel ingots had continually to be increased in weight, that the number of steam hammers had to be multiplied, and that big mechanical workshops had to be built. To this period belongs the adoption of the puddling process, which soon supplanted the cementing process in the production of raw material for crucible steel. At the same time, the experiments for the perfecting of gun tubes, which indeed had been started in the course of the 'forties, went on. They were, however, frequently interrupted, because the manufacture of railway material during this period absorbed almost all the energy of the works. The first orders for eighteen 12-pounder and ten 24-pounder gun tubes came from Egypt, between 1856 and 1858, they were followed in 1859, by the big Prussian order of 300 rough-forged blocks for 6-pounder gun tubes. It was about this time that Krupp took up the designing of guns, thus laying the foundation for the later development of the Krupp gun system. The expansion of the works during the 'sixties, in consequence of ever-increasing orders for ordnance, was very rapid, and entailed the erection of a number of big new workshops.

The evolution of the works so far was on the basis of their old sphere of activity, and of the corresponding application of cast steel. The first germs of this development date very far back, to the experiments for the manufacture of cast-steel rolls, which, on the one hand, tended to improve the methods of handling cast steel for these particular purposes, and on the other hand, produced in the weldless ring for tinsel rolls, the precursor of the weldless railway tyre, the cast-steel rifle barrel, and the cast-steel gun tube. Between the early attempts in the new branches of manufacture, and the final prevalence of cast steel in these domains of application very considerable periods intervened. As will be shown hereafter, it needed lasting and untiring efforts, to attain such paramount success, and it is interesting to investigate the reasons for the slowness of this development. In spite of all the advantages offered by Krupp's cast steel, which were recognised at home and abroad at a comparatively early date, there was one obstacle to its rapid extension, and to the diversification of its application, namely, its costliness, which again was the consequence of the high-class quality of the raw material employed, and of the difficulties attending the process. The high price of crucible steel excluded it naturally from the possibility of competition with any other iron or steel grades, under ordinary circumstances at least, for only quite unusual advantages attaching to crucible steel, could induce a purchaser to use it. It may be proved in almost every case, that cast steel was not adopted for any one branch of manufacture, before the material hitherto used had become unfit to resist the ever-growing strain demanded from it. This observation may be verified all along the line, beginning from the tanners' tools, passing by the coining dies, the rolls, the material for engine and railway building, down to the guns. When the works were still almost exclusively employed in the manufacture of tanners' tools and coining dies, engineering was still in its youth; there was a great demand then for fine tools, such as chisels, drills, engravers' tools, and particularly stamping appliances such as were used by watchmakers, goldsmiths and instrument makers. It was in these circles that German cast steel was first used. Then heavier tools were requisite, as soon as chilled cast-iron rolls which required machining, began to made in Germany. At first the rolling of thin sheet was all done with English chilled cast-iron rolls, or with such made of welded steel. But when a higher polish was required, for instance when the German-silver and brass industries sprang up, an urgent demand originated for hard-steel rolls of the greatest possible purity of surface. The case was the same with reed and tinsel rolls. The steel-pen industry also called for very hard and heavy rolls during the 'forties; then engine building began to develop, and again created a considerable market for cast steel articles. Connecting rods for steam engines and steam hammers, the parts which must bear the greatest strain, were the first that were ordered from the Cast Steel Works. After that came cast-steel crank shafts, because they were a safe guarantee against fractures. Krupp's steel was also applied to steamships and engines, when a greater speed and augmented power was required. The same thing happened in the railway industry, which eventually offered such a large field for the application of cast steel, first as axles and springs, then as weldless railway tyres. The manufacture of cast-steel rifle barrels could only gain ground, after Dreyse had invented the breech-loading system, involving a higher resisting power of the barrel, which hitherto had been made of curved flat bars welded together. The use of cast steel for cannon became inevitable, when the rifling of the bore led to higher velocities, and consequently higher strain upon its walls.

Under these circumstances it is easy to explain why success did not come rapidly, why several decades passed before it was obtained. It was a constant fight against what had become antiquated and insufficient, an incessant strife which only permitted slow progress, but out of which cast steel was to emerge victorious at last. Between the first experiments with cast-steel gun tubes and the first considerable order for such, almost fifteen years elapsed, and it took another ten years before cast steel had firmly established its position in gun making. As late as 1858, the Prussian State railways only used Krupp tyres by way of trial, and in an address to the Ministry of Commerce of the 4th of December, 1858, Krupp complained:—"Considering that I have devoted my life and my fortune to progress which I have finally realised, to the actual benefit of many branches of industry, especially those promoting the means of communication, useful in times of peace and of war, particularly of railways; considering again, that I have refused the most brilliant offers to transfer my inventions abroad, it cannot but grieve me to the utmost, that my establishment should be passed over in such a manifest way, after such loyalty and devotion to the interests of my native country."

Till the beginning of the 'sixties, the Krupp works, even after cast steel had found its widest possible field of application, had essentially remained what Friedrich Krupp had originally intended them to be when he founded them fifty years before, "a manufactory of cast steel and all products resulting therefrom". The works still were a manufactory of specialities, although as such they had developed to an unusual reputation, and still promised to go on increasing. Bessemer's invention of making liquid steel straight from pig iron by a new refining process, certainly the greatest revolution that has ever taken place in the iron industry, at once put a different face on matters; the process was cheap and permitted the production of large quantities at a time, its output was about two-hundredfold that of the puddling process. This invention marks the beginning of the modern iron and steel industry, and by its reflex action, of modern coal mining. Alfred Krupp at once saw the importance of the innovation, and acquired it for the Cast Steel Works. Already in 1862 the first converter was started in the new Bessemer works at Essen. The adoption of the new invention brought about an important and incisive change in the evolution of the works. In 1864 a rail mill was started, which till the year 1905 worked the best part of the Bessemer steel produce into rails. Taking up the production of cheap steel in large quantities, the works developed into large iron works, which in the course of time have gone on expanding their basis and their branches of manufacture, so that to-day they rank among the first of the great German iron works and rolling mills. Towards the end of the 'sixties, the open-hearth steel process was adopted which to-day plays likewise a most important part among the products of the Krupp works. By this process also, high quality steel is produced, available for purposes for which crucible steel is too expensive.

The extraordinary general rise of the works, and the consequent rapidly growing demand for raw materials could not but mature Alfred Krupp's desire to place his works on a broader basis, and to unite in his own hands the entire production, beginning with the raw materials, iron ore and coal, and ending with the finished steel products. His object in doing so was, both to become independent of other sources, and to secure for the works the best possible raw materials, because it was on these above all, that the production of a uniform quality depended. So it happened that, during the period from 1865 to 1873 considerable purchases were made of iron-ore mines, collieries, and blast-furnace establishments. Later on Krupp never missed a chance of expanding and strengthening these foundations of his works.

The rapid growth of the works was naturally attended by changes and measures applied to the internal organisation, which will only be alluded to here. Both the working and the administrative staff had been increased as the amount of work to be accomplished grew. After new processes had been adopted in the field of steel making, and after so many new branches of manufacture had been started, the technical management could no longer, as heretofore, be vested in one hand, but had to be divided up, and much was gained, when the several main departments were placed under so many heads, and a collective procuration, created during the 'sixties, was established, although the definite division of the work of the various departments, could only be settled when sufficient experience had been gained. The all-combining centre of the direction still remained Alfred Krupp. With his never-wearying activity and his all-embracing knowledge, he continued to devote to all branches of the ever-expanding enterprise his interest and his counsel. And by his own example and precept, he kept alive in each department the desire to do the utmost by individual work for the benefit of the whole, yet at the same time he strictly watched over the authority indispensable to the central direction. Thus in the course of years a fixed and settled organisation was created which was codified in a way in the so-called "General Rules and Regulations" issued in 1872. Finally the constant and rapid increase of the workmen employed, occasioned the creation of a number of beneficent institutions which, as time went on, developed into a regular system. Sick-aid and Pension Funds had existed since the 'fifties, the building of workmen's houses was begun in the 'sixties and continued on a large scale in the early 'seventies. With the establishment of supply stores, the building of a hospital and of schools, new fields were entered upon in the subsequent development of this social betterment work.

## CAST STEEL AND THE NEW AGE OF TRAFFIC BY LAND AND WATER.

Up to the year 1849, the manufacture of rolls had mainly determined the development and importance of the Cast Steel Works. After that, railway material was taken up as a new product, and soon advanced to the first place. The early history and very modest commencements of these products have been sketched in the last chapter. Now, with the rapid development of railroads in Germany, and the rise of a German industry for the manufacture of railway material, the time had come for Krupp to devote his whole energy to this new field of action.

The first articles that found favour were cast-steel springs, for which orders came in from the summer of 1849 onwards. German railway-car builders, and a few private railway companies were the first customers. The first considerable order was given in October 1849, by the Cologne-Minden railway company, and consisted of 2400 bearing springs and 400 buffer springs, for which a guarantee of two years was demanded. This company remained a faithful customer ever after. It was the biggest order that Krupp had hitherto received, and the cheerful frame of mind into which it put him, comes out in a letter:—"I have so much work that, for four to six months to come, no order is required. This winter I hope to employ 300 hands." Up to the year 1851, the Cologne-Minden railway company ordered from Krupp springs and spring steel of about 300,000 pounds in weight, and gave the firm a testimonial stating, that Krupp steel had proved an excellent material, very well suited to ensure to a high degree the safety of the service. Other railway companies now followed, the Rhenish railway company sent one of their employees to discuss the question of an order; in 1850, the Austrian State railway gave the first trial order for springs, a litte later cast-steel springs were also ordered by France and Italy. In this field also, Krupp gave evidence of his talent as a designer, by taking a lively interest in developing the ribbed spring leaf which eventually supplanted the system of flat leaves held together by screws.

At first the manufacture was attended by difficulties. A new spring shop was at once erected; the forging, cutting, adjusting, and hardening of the springs had first to be learnt, and was then gradually improved. At first, rolling of spring steel was done at the grooved mill of the Gutehoffnungshütte at Oberhausen. Krupp always sent a foreman to attend to the rolling there, and particularly to the heating of the spring steel. In this way, of course, the net cost of manufacture was augmented, and this proved an obstacle to a successful competition with other spring works, which for the most part used English steel. Comparative tests with spring steel from the various German works were first made by the Cologne-Minden and the Eastern railway. In 1853, numerous trials of the same kind were ordered by the Prussian Minister of Commerce, but the decision of the companies was determined less by the results of these tests, than by the question of price, and especially for the railway companies in the East of Germany the cheaper price of English cast steel was a powerful argument. Krupp, therefore, could no longer put off the erection of a rolling mill of his own, the necessity of which he had already felt for several decades. Both the mill and the 100-horse power steam engine to drive it, were built during the years 1852/53, in Krupp's own workshops, and put up in an annex of the new hammer shop that had been erected a short time before. The mill was chiefly used to roll spring steel, and afterwards also puddled steel. From this time the manufacture of springs became much cheaper, and other works could be successfully competed with. The sale rose quickly, and in 1854 reached its height, for the time at least, with 7000 pieces. It was only ten years later that this figure was surpassed. In the meantime the spring shop was also fully occupied, especially after locomotive springs were made of cast steel, and their use soon became obligatory on most railroads for reasons of safety. In order to compete with the cheaper produce of other works, Krupp at times had been obliged to use puddled steel for his springs, after the 'sixties, however, Bessemer steel was chiefly employed for this purpose, and since 1874 open-hearth steel. Since then, the manufacture of springs has assumed enormous dimensions. Since 1905, the yearly output has surpassed 100,000 piece. During the business-year 1907/08 the steel worked into springs amounted to 6100 tons, *i. e.*, as much as the entire steel output of the year 1862, that is immediately before the manufacture of Bessemer steel was taken up.

The manufacture of railway axles by the Krupp works was attended by many more difficulties. By way of trial, the Cologne-Minden railway had made use of the first cast-steel axles in 1848. The result was so satisfactory, that in 1849, an order for 36 axles was given. About this time other works also took up the manufacture of axles. A serious competitor arose for Krupp in the Karlswerk, near Neustadt-Eberswalde. These small cast steel factories, after having been unsuccessfully carried on by the State for several years, had then stopped work for many years, and had eventually been transferred, free of charge, to the steelmaker Werner, who the same as Grubitz, who succeeded him in 1858, enjoyed in a high degree the confidence and protection of the Prussian Government. Werner took up the manufacture of cast-steel axles in 1849, but he recommended hardened ones for use, whereas Krupp furnished them unhardened. Through the agency of the chief engineer Gruson of the Berlin-Hamburg railway, who afterwards became the famous manufacturer of chilled cast iron, Werner procured one of the first Krupp axles, and used it in Krupp's absence and without his knowledge, for comparative tests with his own axles, the results of which he utilised in his own favour by a circular. This incident retarded the adoption of Krupp's cast-steel axles for more than a year. Krupp at once protested, likewise in a circular, against such a proceeding; he declared that tenacious and unhardened axles were decidedly superior to hardened ones, and he pointed out, that he had undertaken to pay a penalty of 1000 Frederic d'or to the Cologne-Minden company, if one of his axles broke within five years' service, in consequence of a fault of manufacture. At the same time he expressed his willingness to have his cast-steel axles tested alongside of any other product, in an unbiassed manner, in the presence of professional men. Such tests took place in February 1850, before a commission of German railway technicians at the Borsig works in Berlin. The objects tested were cast-steel axles of Krupp and of Werner, compound axles of the Daelen system from the Hörder Hütte, and English patent axles. The superiority of Krupp's cast-steel axles especially when compared with axles of hardened cast steel, came out splendidly. On the contrary, an assembly of German railway technicians who had met at the same time at Berlin, in their "Principles for the building of Railroads", recommended English patent axles in preference to cast-steel axles on the ground, that too little experience so far had been made with these, This fact, and the high price of cast-steel axles still caused many administrations to hold back. It took some time before the greater durability, and the increased security resulting from the use of cast steel also prevailed with these. One thing was certain, the superiority of cast steel was now an established fact for professional people. In June 1850, the Cologne-Minden company gave Krupp their first large order for 325 wagon axles, for which they required a guarantee of five years. The execution of this order was the beginning of the manufacture on a big scale. Up to 1857, this company ordered from Krupp over 2800 wagon, tender and locomotive axles, which means 54 per cent of all axles that had so far been made. Slowly, and mostly by small orders as experiments, the other German railway companies followed suit; the Berlin-Anhalt railway, the railways of Baden, Saxony, Austria were among the earliest regular customers.

The first considerable order for axles occasioned the erection of a new workshop which started work in summer 1853. It was a fine building of several stories, in which were put up the first 40-horse steam engine and numerous turning-lathes, and most of the machine-tools that had been set up in the foundry, the old building dating back to 1819, were now transferred into the new shop, and thus the first building of the works restored to its first and original purpose; that of the crucible and steel manufacture. On the 8th of May 1853 Alfred Krupp's engagement to be married was celebrated on the upper floor in the new workshop, in which no machinery had been put up as yet, in the presence of all the employees of the work. The number of hands employed in the new shop rose in a few years from 80 to 300. The first turning lathes for weldless tyres, for heavy crank shafts and for mounted wheels, the first hydraulic press for fastening the wheels on the axles, the first boring benches for guns, were, in the course of years, put up here. When, after 1858, a number of other workshops were erected for special purposes, the first and older one received the denomination of mechanical workshop No. I, which it preserved during all additions and alterations, until it was pulled down in 1907, when it had to make room for the erection of the big new building for the head offices of the administration. Its work and equipment has been removed to a fine new erection, built in accordance with modern requirements.

There were still all sorts of obstacles to overcome before the absolute supremacy of cast-steel axles for the rolling stock of railways was established. Part of the Prussian railway administration obstinately adhered to their prejudice in favour of hardened axles, and could only be convinced of the danger they were to the safety of the service, by repeated accidents. Nay even Krupp himself, who had, on several occasions, publicly warned the companies not to use them, was required by some railway administrations, contrary to his own most urgent advice, to furnish a considerable number of hardened axles. As could be foreseen, a number of fractures occurred in the course of the following years, which gave rise to violent attacks on cast-steel axles in general, and Krupp axles in particular. In a circular of November 1857, Krupp explicitly stated the actual condition of affairs, and pointed out that among 5000 axles or thereabout, made according to his prescription, not a single case of fracture had occurred in regular service, and that the cases which had happened were only due to want of knowledge, or to the obstinacy of those who ordered the axles. Such incidents, however, considerably retarded the general adoption of cast steel for axles. Also the design of railway axles had to be altered, if the advantages of cast steel were to be fully enjoyed. Most fractures happened about the seat of the boss, where the axle then used to be turned down to a smaller dimension than in the middle part of its body, the shoulder thus originating a sharp corner in the angle. Krupp drew attention to the fact in word and by writing, that exactly in this place between the rigid boss and the vibrating middle part of the axle the stress is greatest, that here therefore the diameter ought to be greatest. He also pointed out that at the foot of any shoulder-stud or other projection, abrupt sharp angles should be avoided in passing from one face to the other, but that the transition should in section form a curve, because cast steel is apt to crack in any sharp corners. Krupp had to fight for these principles for a long time, although, whenever a fracture of a cast-steel axle occurred, he could unvariably prove that the fault was some neglect of the rules he had laid down.

Alfred Krupp had from the very beginning seen that cast-steel axles were a product likely to conquer, not only the home market, but also that of the world in its widest sense. As early as 1849, he presented to the Pennsylvanian railroad company two wagon axles which were placed under a tender, which during five years' use ran over 80,000 English miles, after which the axles were inspected, found to be as good as new, and again taken into use. In 1851 Krupp sent a cast-steel wagon axle to the London Exhibition, where professional men of all countries met. Men of authority in railway matters, such as Engerth of Vienna, the builder of the Semmering locomotive, and afterwards the Swiss engineer Riggenbach, became warmly interested in Alfred Krupp's cause; so did also, after 1856, the chief engineer of the Paris-Orleans railway, Polonceau, who was fully convinced of the excellent qualities of cast steel for railway material. He had thorough tests made in his own workshops of iron axles and cast-steel ones, and in an official testimonial called their qualities "magnifiques"; as regards strength and durability there was no comparison between them and iron axles. The Orleans company immediately equipped an Imperial train of nine carriages with Krupp cast-steel axles for the sake of safety, a fact which was much discussed in the papers. So orders for axles rapidly augmented, and a new difficulty arose to secure sufficient numbers of skilled workmen. Turners who came from other works were frequently of little use for the working of cast steel, which was quite different from all other kinds, so that the foremen preferred to train or initiate men taken from among the number of their own locksmiths. It must be mentioned that even after the superiority of cast-steel axles had been universally established, many companies continued to use iron axles on account of their lower price. Only when the speed of trains increased and the weight carried by wagons augmented, builders were obliged to use crucible steel, until later on ingot steel provided a cheaper material which was also reliable. Up to 1864, the works had, on the whole, turned out 12,000 railway axles, soon after that, however, the yearly output rose to 10,000 axles, and eventually to far more. Krupp now had the further satisfaction of seeing that all professional circles and authorities adopted his prescription as to the design of axles. In 1869, a technical commission of the Union of German railway Administrations declared a load 30 per cent heavier permissible for cast-steel axles, and their construction was prescribed exactly on the lines of those principles which Alfred Krupp, fifteen years before, had pointed out as being the only ones guaranteeing reliability.

Soon after having turned out the first wagon axles, Krupp also tried the manufacture of axles for tenders and locomotives. The engineering works of Wöhlert and Borsig at Berlin gave the first orders for heavy crank axles, at the beginning of 1852, and some time before the Rhenish Steamship Company at Cologne had ordered a few shafts. For such work the old hammers proved insufficient, and again, as in former years, Krupp had recourse to the kindness of the Gutehoffnungshütte, which works were then already fitted with heavy hammers. The 4300 pound ingot for the London Exhibition in 1851, had also been forged there. Krupp took all possible care to get these jobs done cheaply and yet well. Covered up in ashes, the red-hot steel blocks were transported on an iron wagon from Essen to Oberhausen, and the most experienced of the smiths of the Cast Steel Works was deputed to superintend the work. But this was a makeshift impossible to keep up permanently. The small hammers Krupp had bought at Borsig's and Wöhlert's in 1851, were out of all question for forging such heavy pieces, and so Krupp decided to build a big hammer of 80 to 100 hundredweights, worked by steam. The greater part of the money required for the hammer, as well as for other extensions made in those days, was furnished by the sale of the English spoon-mill patent in 1851. The new hammer shop, situated alongside the Mülheimer Chaussee was, from the beginning, allowed a length of 80 meters, for Krupp well foresaw that the first hammers would soon be followed by others. In designing his hammers Krupp again followed his own conception. Some ten years before, for a similar purpose, that is for the forging of the heavy iron shafts for ships, the Nasmyth steam hammer had been invented in England, the biggest hammers of this kind were set up in the iron works at Low More and at Le Creuzot, but none of them had the weight which Krupp desired to give to his new hammer. The cost of an English steam hammer of the desired weight would have been entirely beyond his means, nor would the building of such a hammer in his own works have been feasible, on account of the difficulty of its construction and the weight of the big castings, especially the two standards. Krupp had, therefore, to chose a simpler design, if he wanted to build the hammer himself. He retained the construction of the old helve hammer with a wooden shaft, but he replaced the camshaft which lifted the hammer by a steam piston, the huge cylinder of which was placed under the hammer shaft, and could easily lift the hammer which weighed 100 hundredweights. This hammer, which came into operation in June 1852, worked to satisfaction until the end of the 'sixties, and has had many successors of the same type. The Gutehoffnungshütte furnished the boilers and the big cast-iron parts, such as the hammer head, the anvil block, and the cylinder. They were, some of them, castings of unusual size and weight, and their transport to Essen caused some excitement. When they were taken across the Emscher, the bridge had to be considerably strengthened for the purpose, the horses were unharnessed, and a few hundred workmen carefully pulled the load across. This manner of transport became usual at the Cast Steel Works for very heavy pieces. Krupp was now in a position to forge any object that was demanded, but now machine tools for the machining of them were lacking. The first locomotive crank axles therefore were furnished rough forged, but this again, as had formerly been the case with rolls, led to all sorts of painful incidents. One of these crank shafts, which Wöhlert had machined for a locomotive engine of the Eastern Railway, was fractured at the crank, in consequence of a shock in 1854. Here, again, was an instance where one of the fundamental rules that machine elements made of cast steel should not have any sharp angles or incisions, had been neglected from ignorance. The crank pin was worked on the crank without a groove at its base, and it had been in the sharp angle at the base that the first crack had formed. The opponents of cast steel made great capital out of this occurrence, but Krupp defended himself bravely and with success. Even in November 1856, in a paper he read before the Society for the Study of Railways at Berlin, he returned to this incident, pointing out that all the distinguishing qualities of cast steel could be destroyed by mistakes in treatment and construction. The fractured axle was afterwards very closely examined and subjected to the severest tests possible, in order to prove the purity of the steel, parts of the same axle were even exhibited in 1855 at the Industrial Exhibition of Paris, some of them fractured by force, some of them bent in the cold state under the steam hammer, and were greatly and unanimously applauded by the jury. Nevertheless, it seemed necessary to prevent similar occurrences, and this was only possible if the works delivered such heavy pieces in a finished state. So here again inexorable necessity drove Alfred to extend his workshops, as he had been driven for years, to Friedrich Sölling's horror, from one extension to another. The machining of crank shafts caused some difficulties at first, and they were even later on delivered rough-forged wherever sufficient knowledge on the part of the customers could be relied on, because the profits returned on them were greater. The first important order in this line were twenty heavy locomotive crank axles to the Paris-Orleans Railway, in 1857. After twenty years' service, confirmation was given to the firm that nearly all these axles were still in use and intact, although some of the corresponding engines had run over more than 590,000 kilometers. The confidence, therefore, which the French technicians had placed in cast steel had been splendidly rewarded. Both English railways, among others the West Cornwall railway in 1854, and German and Austrian locomotive building works, forced by the ever increasing demand of engines, and the frequent occurrence of fractures of iron and welded-steel axles, gradually passed over to cast-steel crank axles. In consequence of growing orders in this line and simultaneous orders for cannons on the part of various States, Krupp was obliged to build a second helve hammer in 1856, weighing as much as 140 hundredweights, and a little later a smaller one of 70 hundredweights. The castings for these hammers were made in the works' own iron foundry, established in 1854. In spite of their rather old-fashioned design both hammers did useful work until the 'seventies. Orders for locomotive axles now came in more regularly, but their production on a large scale was still retarded by the high cost price. When Bessemer steel was introduced, Krupp believed that this steel would furnish a suitable raw material from which to make such axles cheaper than hitherto, but still of sufficient resistance; but he was soon convinced that Bessemer steel was no substitute for crucible steel for such objects. He therefore steadily refused all orders for Bessemer steel locomotive axles, until later on open-hearth steel furnished a reliable material, which was much cheaper than crucible steel.

The manufacture of shafts for ships was taken up by the Krupp works first in the year 1852 with two shafts of light weight for the quick boats of the Cologne Steamship Company, the 'Stadt Strassburg' and the 'Prinz von Preussen'. As with the first order for railway axles, so with these again Sölling had been the mover. In consequence of the inadequacy of the equipment of the works the shafts took some time in getting finished, but soon after the first heavy helve hammer had been built, the same company ordered a heavy paddle-wheel axle of twenty-nine hundredweights. Other steamship companies followed, that of Düsseldorf, the Saxo-Bohemian, and the Austrian Lloyd, the first to use Krupp shafts in sea-going steamers, gave important orders to the Cast Steel Works during the years 1853 to 1857, there were shafts among these weighing up to 60 hundredweights. In 1855 the first propeller shaft of cast steel was furnished, it was destined for a screw yacht for the Viceroy Said Pascha of Egypt, who also took an early interest in Krupp's guns, in his railway material and cuirasses. In the summer of 1854, Krupp exhibited at the Industrial Exhibition at Munich, a forged crank shaft for steamships, which procured him the custom of several steamship companies for the traffic on the Maine and the Danube. In the following year, one of the shafts intended for the Rhenish steamship company at Cologne was sent to the International Exhibition of Paris, where it attracted the attention of French technical men, alongside of a cast-steel ingot of 5000 kilogrammes, a cannon tube and several railway axles and tyres, which had been bent in the cold state. Krupp at once availed himself of this success to offer the French Ministry of Marine cast-steel shafts for some of the new French war ships, the building of which was energetically pushed forward after the Crimean war. He was given an order for a two-throw cranks haft and for four straight propeller shafts 30 foot long, 1 foot in diameter, and weighing from 110 to 120 hundredweights. These were the first cast-steel shafts ever used in war ships, and by far the biggest pieces that the Cast Steel Works had so far turned out. These propeller shafts required ingots almost twice as heavy as the one that had been exhibited in Paris. Nevertheless Krupp cheerfully accepted the order, which was a job after his own heart, being worth upwards of 130,000 Francs, and furnishing most welcome employment for the 140-hundredweight hammer which had just been finished. It is true that he had no machine tools, as yet, to work such heavy shafts, he even lacked the room to put up benches of the required length, for the first mechanical workshop was already full up. He tried to induce the French Ministry by a considerable reduction of price, to take the shafts nonmachined, but when this was declined, he never hesitated for a moment to take the order all the same. He bought the turning lathes required, and set them up temporarily in a glass-roofed annex on the east side of the first mechanical workshop, where he started them to work almost immediately. In October 1856 Krupp sent his French agent a chip of one of these shafts 230 feet long, to show to the French Marine Engineers as a sample of the tenacity and homogeneity of cast steel. The task now set before Alfred Krupp was, to make the most of the new extensions of his works, and to obtain permanent and sufficient orders, which in those times was not by any means easy. Uncertainty in the political situation, and rumours of war caused business to stagnate during the years 1858 and 1859, and the Cast Steel Works also had to suffer from that, Krupp's offer to Russia to furnish the entire shaftings for forty frigates which that country was planning to build was, however, not successful, although he was prepared to give any guarantee demanded, and a credit of three years. The orders too coming from the commercial fleet grew less. For nearly three years the number of workmen remained stationary at 1000 odd, which they had attained in 1857 Yet Krupp so clearly foresaw a new rise of business that towards the end of 1858 he began designing a gigantic hammer of 600 hundredweights, "in order to be able to forge ingots up to 50,000 pounds for Leviathan shafts and other massive objects." This was the historical hammer "Fritz", which was built in the year 1859/61 with an expenditure of 600,000 Talers, and which struck its first blow in September 1861. In designing it, Krupp followed the principle of the English steam hammer, but he deviated from it in many particulars suggested by his own many years' experience in forging huge masses, as for instance, in the fundament for the anvil-block which he made excessively heavy, but very steady in return. Krupp's agents had travelled about Westphalia in order to buy the strongest oak trees they could find, which laid side by side lengthwise, were to form the first base on which the real foundation, a bed composed of huge masses of iron, such as never had been used for such a purpose before, was to repose. When later a hammer of the same power was erected in Russia for the forging of guns, after the model of "Fritz", this hammer would not work satisfactorily, in spite of all the care that had been applied to its making, as a matter of fact only the visible parts had been copied, and those concealed in the ground had been neglected. The hammer "Fritz", which afterwards was changed into one with a weight of tup of 1000 hundredweights, has remained the biggest hammer of the works, just as its gigantic chimney remained for decades the beacon of the works, overtowering, as it did, all other chimneys. When this hammer was building, it excited the admiration of all the world, it seemed undertaken with so much, and such unusual daring, that many looked upon it, as an audacious freak of Krupp's unbounded love of enterprise, and predicted a sad end to it, and yet Krupp was only pursuing the road shown by necessity and experience, which had taught him that as the demands on the power of resistance in cast steel grew, the enlargement of the hammers, carried on step by step, as had hitherto been done, would be inadequate to keep up with them, and that it was better to anticipate necessities at one bound for a long time to come. Those who criticised Krupp, besides, evidently were ignorant of the great resistance cast steel offers when forged, so that for such forgings heavier hammers are required than those used for iron or welded steel.

How correctly Alfred Krupp judged and acted, in building this enormous tool, is proved by the fifty years' work it has done, all the time rendering most useful service to the Cast Steel Works. A plan has at different times been considered of building a still bigger hammer, the "Hercules", but this could be avoided since "Fritz" was always able to meet all the requirements. Only in modern times has it been supplanted by the more efficacious work of the hydraulic press. To make room for new installations of this kind "Fritz" was finally pulled down in 1911 after fifty years activity. On the 4th of March of that year the last forging was placed on its anvil, and just as on the 16th of September 1861, the grandfather Alfred Krupp had watched with anxiety and yet with confidence the first sounding strokes of the gigantic hammer, so now his granddaughter Mrs. Krupp von Bohlen und Halbach, at the side of her husband, was a witness of its last piece of work. In a short address by which the director who has for many years been at the head of the steel department of the Cast Steel Works, celebrated this last job of the hammer "Fritz", the importance which that great deed of Alfred Krupp had for the Cast Steel Works was described with these well-chosen words:—"What a wonderfully perfect piece of work it must have been, to have been able to resist for so many years the progress of time, always so eager to substitute the better for the good. To create or conceive it, required a man like Alfred Krupp, who, a long way ahead of his contemporaries, endowed with a firm will and perseverance, strong and tenacious as his steel, could design this tool which, to the notions of those days, was a prodigious performance, could complete it, and render it serviceable to his purposes. If within the circle of his own engineers his plans were regarded with misgivings, technical men outside actually distrusted and derided his ideas. Nay, there were prophetic minds that maintained the hammer would never strike a single blow. Even the head fitter, who superintended the erection of the hammer, confessed later, that he had apprehensions when he witnessed the first stroke. Soon, however, the reliability and the power of output of the tool were recognised, which, until forging presses took its place, played so important a part in the glorious development of cast steel."

The development Krupp had foreseen, extended to industry and commerce in general; from the beginning of the 'sixties, a lively upward movement set in, which largely promoted railway and steamer traffic, and brought Krupp considerable orders for crank axles and marine shafts. In 1861 the Hamburg Packet Boat Company, the Hamburg-America-Line of to-day, ordered the first cast-steel shafts for their transatlantic mail-steamers. During the next year orders followed from the North-German Lloyd, the crank shafts for this company surpassed in weight all former ones. The hammer "Fritz" was ready in time to take on this work, which now became too heavy for the helve hammers; his first job was to forge a cast-steel ingot of 20,000 kilogrammes for the London Exhibition of 1862. It was four times as heavy as that which had been so much admired at the Paris Industrial Exhibition. Besides this ingot, Krupp exhibited in London two heavy forged crank shafts, one for the German Lloyd, the other for the English Holyhead Company. It was just then a period, during which the speed of vessels and the power of engines were rapidly increasing. Fractures of iron shaftings were an every day occurrence in spite of their weight, from the ever-growing strain put on them. Naval engineers, however, in those days still had a certain aversion to steel shafts, because to their experience, only however gathered from welded-steel shafts, they lacked tenacity and a fracture would, as a rule, disable the ship immediately and entirely, while an iron shaft, though cracked could go on working for some time, if carefully handled. Now these new heavy cast-steel crank shafts were exhibited, which during a ten years' trial had proved that they combined the resistance of the hardest steel with the tenacity of iron. Their success was brillant, during that same year twelve big marine and propeller shafts of a total weight of 90,000 kilogrammes were ordered, similar orders came in 1863. In those days every large German ship was still built in England, it spoke all the more for the reputation of the Cast Steel Works when the North-German Lloyd insisted on having Krupp cast-steel shafting put into the ships they had built in England. These orders were also financially of great importance to the works, considering the prices that were paid in those times for finished crucible steel shafts. A crank shaft for the North-German Lloyd in 1863, the heaviest that had been made so far, fetched 30,000 Talers. In technical respects also, these orders meant progress for the works. Enormous cast-steel ingots were now produced in the foundry, which had been added to almost without interruption, and since 1860, had worked with furnaces containing twelve crucibles. On the 28th October 1863, in the presence of the Ministers of War of Belgium and Russia, a casting was done from 848 crucibles. The ingot was intended for an English crank shaft weighing 24,375 kilogrammes. The hammer shop also had to be extended about this time, the number of steel hammers rose during the period 1862 to 1866, from 17 to 47, the weight of their respective tups, from 80 to 160 tons. Besides "Fritz" a second big hammer of 400 hundredweights had been erected in 1863, the hammer "Max", likewise principally used to forge axles, shafts, cannon tubes, and heavy ingots for tyres; after forty-six years' activity it was pulled down in 1910.

The manufacturing cost of heavy marine shafts was of course very considerable. Only the lower and absolutely pure part of the crucible-stee ingots was used, and the complicated design of crank shafts caused further loss of metal during the processes of machining and finishing. The ingots therefore were nearly twice the size of the finished axles and shafts. The cooling down of the ingots, after the casting, had to be conducted with great care, and sometimes took months, so as to avoid any dangerous internal stresses. For this reason Alfred Krupp had trials made, as early as 1863, to produce heavy crank shafts at once in their finished shape by casting, so that only slight machining for the finish would be required. It would be possible to sell such shafts at much lower prices. He was well aware of the difficulty of the problem, but he did not doubt that it would be solved some day, and he prophesied that he who found the solution would have an enormous sale of locomotive and marine crank shafts. "I will remind you" he wrote in 1875, referring to his former suggestions, "of the Chimborazo of my wishes concerning castings for steel axles, which in any case, even if cast only, will be stronger than forged-iron ones. They are sure to be made one day, and it would be very awkward, if others ran ahead of us." Trials were indeed made in this line in the course of the 'seventies and 'eighties, but with no result. Again and again experiments resulted in the conviction, that a thorough forging was indispensable in order to obtain steel of such tenacity and homogeneity, that it could resist the greatest strains placed on it. Only the improved technical practice of modern times has succeeded in perfecting steel castings to a degree, that even crank shafts obtained by this method can be safely used for many purposes. Also other hard-worked elements of machinery and engines, such as locomotive spoke wheels and others, are now produced in large quantities in the steel foundries of the Krupp works. In the meantime, after the open-hearth process had been adopted, many axles and shafts that were not required to offer the greatest possible resistance, were made from ingot steel on account of its lower price. There have even been times, when it was believed that mild ingot steel, and even wrought iron ought to be preferred for heavy shafts, not on account of its cheaper price, but from technical reasons. As with the first locomotive axles, so with marine shafts, grave mistakes were committed in their design or during their use. Among technical men in naval circles, the troubles occurring were attributed to the hardness of the cast steel, and mild iron came into favour. Following this current of feeling during the crisis of the 'seventies, an increased manufacture of heavy wrought-iron shafts was also considered at the Cast Steel Works, in order to keep the hammers employed, but Alfred Krupp's paternal affection for cast steel, which he had raised from its very small beginnings to its present powerful position, revolted against this. "Let iron be forged to any extent for all those things that can be made of iron, but not to supplant cast steel", was his reply to every proposition made to him to that effect. He called this predilection for mild material a mere fashion that would soon pass over. He exhorted his fellow workers not to be influenced by the opinions of the day. He had, in his time, to fight the fancy for too mild steel for locomotive and wagon axles. "It is the same kind of mistake as that against which I had to fight twenty years ago, when all steel axles were required to be hardened." The hardness and elasticity of the axles had to be suited to their various applications.

Iron shafting only had so far been used in German war vessels, which down to the middle of the 'seventies were exclusively built in English yards. A gradual change came about in this respect, when General von Stosch was placed at the head of the German Navy, a man to whom the promotion of German shipbuilding owes much. The Bill of 1873 for the foundation of the Navy provided that war vessels should, as far as possible, be built in German yards. Now the moment at last seemed to have come for securing a prominent part for cast steel in the German Navy, although the question of price still constituted a serious obstacle. In 1875 Krupp offered the Imperial Admiralty a cast-steel shaft, by way of trial, for one of the ships on the slips. Krupp meant to utilize for this shaft the huge ingot of 52,000 kilogrammes, which had been exhibited at Vienna in 1873, and offered it to the navy at an exceptional price, not higher than that of an iron one. He asked in exchange to be permitted to exhibit the shaft, before it was delivered, at the International Exhibition at Philadelphia in 1876. The Admiralty accepted the offer, and gave an order for a three-throw crank-shaft for the 2500-horse main engine of the corvette with decked battery 'Stosch', which was launched in 1877, as the first ship of a new division of corvettes armed with 17-cm Krupp guns. So the first German war ship, which carried out on to the ocean Krupp's steel not only in the shape of armament, but as an essential portion of her motor mechanism, was baptised by the name that was so closely bound up with the promotion of national defence and national work in Germany.

The first natural consequence of Krupp's connection with the operative departments of the railway companies, which had begun by the supply of tool steel, was the development of his axle and spring manufacture. The road which led to the cast-steel railway tyre was not quite so smooth, and yet this invention had a greater success than any other in the various fields of Krupp's activity in the service of peaceful pursuits. The ascent from small beginnings to final success was here again most wearisome. It needed all the energy and perseverance of a man like Alfred Krupp, to overcome the opposition of what was sanctioned by tradition; besides the task demanded all sorts of sacrifices. But when it was successfully achieved, when the durability and security of the weldless tyres carried the name of Krupp, and the trade mark of the three rings, all over the globe, the persistence of their maker was recompensed also in a material sense. Krupp, as was his wont, refused to use his success for the benefit of his own personal objects; it was to him nothing more than another step upwards, and a means of furthering the evolution of his works. The astounding expansion of the works during the 'fifties and 'sixties, and not less the many years' experiments directed to the improvement of ordnance, by which endless sums were consumed, were only rendered possible by the large returns he realised for several decades through the manufacture of tyres. As early as 1843, Krupp received the first suggestion to employ cast steel for railway tyres; it was through the director W. Lueg of the Gutehoffnungshütte, which works were then intending to take up the building of locomotive engines. Lueg was looking out for a subsitute for the mild iron tyres, which wore away too quickly, and asked Krupp if in his opinion hardened cast-steel tyres would answer the purpose better. Krupp thought not, at least not in the way proposed, and remarked that the tyres would probably fracture while being shrunk on. A little later, trials were made by several works with welded-steel tyres, which were also put to use here and there, without any lasting success. As late as 1847 the Review for the Progress of Railway building, after having examined the results so far obtained in this line, came to the conclusion that security against fractures had in no way been enhanced by the use of steel, and that the longer life of steel tyres alone was not sufficient to compensate for the higher cost. To the welded-steel tyres of those days this judgement justly applied, and cast-steel tyres did not exist then. Lueg's suggestion had at first remained without any result for Krupp. The great number of other enterprises which kept him fully engaged during the 'forties, and the precarious financial situation of the works during those times, were little suited to the taking up of so difficult a problem. Besides, locomotive building in those days was almost entirely in the hands of English firms. Not before

German industry energetically had taken up the manufacture of railway material, and locomotive works had sprung up in the north and south of the country, and Krupp, since 1848, had become involved in the movement by the first orders he received for springs and axles, did he again begin to consider the question of tyres. The manufacture of safe locomotive wheel tyres excited lively interest among technical men in the industrial district of Rheno-Westphalia. One of the best-known engineers in the west of Germany, R. Daelen of the Hermannshütte, who afterwards for many years was the head engineer of the "Hörder Verein", invented, about the beginning of 1849, a rolling mill for the manufacture of railway tyres from iron bars rolled up spirally and welded together. The same year, Krupp started experimenting on the manufacture of the weldless tyre. The possibility of producing such rings was proved by the many years' practice of making tinsel rolls, but the way of procedure used for such rings, namely, to pierce a cast-steel disc-shaped block, and to widen it out by forging, seemed little suited to the present object. Krupp, therefore, set about the problem in a different way. A bar of a fairly big square section was split lengthwise and opened out by driving wedges into the slot, until it finally assumed the shape of a circle. In this way, with very little loss of metal, a ring without welding seam was obtained, on which the flange had to be worked by turning, forging, or rolling. The first trials, which were carried out on a very much reduced scale, took place in August 1849; for undertaking them on a natural size scale, especially for bringing out the flange, the works did not then possess the necessary tools. Even the making of small rings had proved to be a task of great difficulty. At about this stage of the problem the great orders for railway axles intervened, which, by the way, also required new extensions and kept the works completely engaged. Alfred Krupp was not the man to fritter away his energies at so important a conjuncture, and therefore laid aside his tyre experiments for the time being.

The trials were only resumed in January 1851, and then on a different basis. The Cologne-Minden railway at that time declared its readiness to have a few of Krupp's cast-steel tyres shrunk on and used in the regular service. But as the manufacture of large tyres was impossible with the appliances the works then had at their disposal, casting them was attempted. It seems that the suggestion of this solution came from Alfred's brother, the inventive Friedrich Krupp, who, after a long absence was once more active at the works. Two different ways were tried for getting the necessary density of the casting. A horizontal mould lined with graphite was rotated during the casting, by which it was intended that the liquid steel should be firmly pressed against the outer face of the mould by centrifugal force. Another way was to cast in vertical moulds with a very big runner, a method still applied at the Cast Steel Works. The experiments were gradually carried out on bigger scales, rising to castings from 18 crucibles. Both methods seemed to promise good results. When Alfred went to London in April to make preparations for the Great Exhibition in 1851, he believed that he had arrived at the solution, and he even hoped to be able to exhibit his first tyres there. But this was anticipating matters. When these trial tyres were turned, it was seen, that they could not stand any comparison as regards purity and resistance with well forged cast steel, and Krupp after that gave up the hope of solving the problem along these lines. He was detained for some considerable time in England by the London Exhibition, and by the sale of his spoon mill at Birmingham. The tyre experiments therefore could only be taken up again in September, and this time on the old method of slotting forged bars, but Krupp set to work now more systematically. As was his habit, he started on objects of a reduced scale, and gradually proceeded to pieces of bigger size, and never stopped until he had reached his goal. "My first hardened roll", he afterwards wrote, "was as thick as a finger, and my first tyres and disc wheels could be easily hidden in a glove. My first gun was one foot long." The slotting and working into ring-shape of the square-sectioned forged bars was at first practised, in a third, then in half, eventually in the full natural size of a tyre. The flange was produced by forging between appropriately shaped anvil and hammer faces. All the rest had to be worked out by machining on the bench, that is to say, on the lathes of other works, since Krupp himself had none of sufficient size in his shops yet. The first turning lathes of twenty-four inches height of centre which were suited for that kind of work, were not bought by Krupp till 1852, but already in December 1851 the first trial tyres had been delivered by the works. Alfred Krupp in person delivered one, made in half the natural size, to the Prussian Minister of Commerce, who had it exhibited in the Railway Section of the Ministry of Commerce. The first full-sized forged tyres were delivered to the Eastern Railway Company, which finished them in their workshops at Berlin, and had them shrunk on. To protect his invention, Krupp had, in 1851, made an application for a patent in England. In December 1852, he also applied for one in Prussia for a period of 15 years, the longest allowed by the law. It was granted him, however, only for 6 years to start with, and the machinery and the appliances used in the manufacture of tyres were not comprised in it. Only after repeated and urgent entreaties, did the Minister of Commerce prolong the patent to a period of altogether 8 years. This was a short space of time, considering the preliminary difficulties that had to be overcome before the regular remunerative manufacture could be started, and those that would oppose the sale at first. All the tyres that Krupp had made as yet had been forged under the hammer, he did not yet possess a rolling mill. In order to facilitate the machining on the lathe, the square-sectioned forged bars were stamped in a matrice before they were slotted, so that a rim was formed on the upper edge which eventually furnished the flange. After the slotted bar had been opened out, and had assumed a circular shape, it was given the requisite diameter by subsequent forging, which also brought out the flange fully. This method so far was certainly an improvement, yet not one suited to manufacture on a large scale. Quick and cheap production could only be obtained by rolling. Krupp also attacked this problem, starting with the simplest means. He first tried to roll out rings of soft metal on a minute scale, between two steel rolls fastened on the axles of a spoon-rolling mill. From trials with tin and lead, he passed on to such with red-hot iron and steel. About the beginning of 1853, many such railway tyres, hardly measuring a span in diameter, were made, which Krupp gave away as presents to friends and acquaintances. In the German Museum for the Masterpieces of Arts and Crafts at Munich, where the manufacture of weldless tyres has been represented by word and picture for the benefit of posterity, a few of these first specimens are still preserved. Through such experimental work he gradually discovered the fundamental lines for the design of his first tyre-rolling mill for practical use. But all the tyres delivered in 1853, by way of trial specimens to the Cologne-Minden and Vienna-Raab Railway Companies, to England, and to the United States were made without the aid of a rolling mill, simply through the dexterity of Krupp's hammersmiths. The testimonial given by the Cologne-Minden railway after the lapse of a year, was to the effect that the two trial tyres had proved extremely resisting. The direction of the Vienna-Raab railway had the tyres deformed and destroyed by violence. In the course of these tests they were bent perfectly flat in the cold state. This company expressed, in a most unreserved manner, their approbation of the "excellent qualities of the cast-steel tyre". These tests created a considerable sensation among professional men, Engerth read a paper on them before a meeting of Austrian engineers, the technical papers discussed them at length, and the Ministry of Commerce in Vienna drew the attention of the Austrian State railways to Krupp's cast-steel tyres.

In November 1853 the first tyre mill was erected. It is true that many changes had to be applied to it afterwards; in fact the mill could only produce faultless work in the June of the following year, and this was still rather slow. The mill was of an extremely simple design, it chiefly consisted of two small rolls which squeezed the tyre together as it passed between them, and of a conical roll which was pressed horizontally against the edge of the tyre, thus producing the flange by lateral pressure. The addition of this third roll which only worked satisfactorily after many trials, constituted the main progress of Krupp's tyre mill, as compared with older mills of similar kind. When a lot of tyres had been rough-rolled in this way, two grooved rolls were put into the mill, between which the tyres were finished. This mill offered the advantage that with a small number of rolls any desired profile could be produced, but its output was very small, and the tyres produced therefore very expensive. Another drawback connected with it was, that it had no driving-engine of its own, but for reasons of economy was coupled with the spring and general grooved mill, so that only spring steel or tyres could be rolled at the same time, yet such, as it was, considering the scanty orders that came in for tyres, it sufficed for the present. The Prussian Eastern railway and the West Cornwall railway placed small trial orders only in November 1853. Further orders came in 1854 from Vienna, Dresden, Graz, and most of the German companies followed in the course of that same year. Although in each single case the orders comprised a few pieces only, they nevertheless were welcome, because they helped to solve the many questions that were naturally connected with the use of the new material:—the required hardness, the machining, the allowance for shrinkage, the secure fixing of the tyres on the wheels, &c. The Industrial Exhibition at Munich of 1854 was attended with wonderful success for the recognition of Krupp's perseverance, in the south of Germany. He exhibited a tyre there which was bent right together without showing any cracks. Besides, he came into personal contact with Engerth and other influential railway engineers. Krupp declared his willingness to guarantee a life of 20,000 German miles for cast-steel tyres, before they had to be turned off again on the lathe. In November that year, Krupp at last received the first order of some importance, namely 80 tyres for the Nuremberg wagon-building firm of Klett & Co. The Cologne-Minden company, fully satisfied with the results obtained with the first trial tyres, ordered in December 400 tyres; these made the beginning of the manufacture on a large scale. Five years had now gone by, since the first experiments had been started, and yet this big order came almost too early for the stage at which the manufacture had arrived. Alfred Krupp, who was as yet in no way satisfied with the working conditions of his first mill, would have liked to refuse the order for another six months, because he was revolving in his mind the intention of considerably extending and improving the equipment for the tyre manufacture, hoping that after the execution of his plans, he would be able to work much more cheaply, and consequently with much larger profits. During the whole summer of 1855, he was engaged in designing and draughting a new tyre-rolling mill of greater output, which was built in the following winter. To the south-eastern portion of the hammer shop a large annex was added, and a 200 horse power steam engine erected in its centre. At each side of this engine a complete mill was put up, each consisting of a rough-rolling and a finishing frame. Both mills were surrounded by a semicircle of six heating furnaces from which the tyres could be lifted straight into the mill. The general arrangement of the mills was retained, but the productive power had been raised by making the individual parts much stronger. In February 1856, the erection of the mill was completed, and Alfred Krupp announced the good result to Sölling, saying:—"The tyre-mill works wonderfully well. To morrow it will start on the execution of regular orders, I only wish now, that I could get orders of 20,000 to 25,000 piece per annum for the next ten years." The tyre-rolling mill was the greatest success in design that Krupp had so far achieved. After rolling, the tyres were placed on a centering apparatus which gave them the exact diameter and circular shape, by means of four circular segments that were pressed against the inner face of the tyre. In the first centering press the pressure was obtained by a screw. It was not till 1860 that a new hydraulic press of the system still in use was built. A sketch of this machine from Alfred Krupp's own hand, still exists.

The output in 1855 amounted to between 700 and 800 tyres. Orders had been given by Austrian, French, Italian, and English railroad companies, German private companies and locomotive works also showed confidence, the Cologne-Minden Railway, in the beginning of 1856, placed an order for 600 tyres. Only the Prussian State railway still held back, in a certain measure justifiably so, for the experimental stage had not yet been entirely left behind, and the manufacture was not altogether free from occasional mishaps. Most of the tyres in those days were furnished rough-rolled, and were finished and shrunk on in the workshops of the railway companies. In these operations they were frequently handled in the same way as iron and puddled-steel tyres had been, which means in a way absolutely unsuited to cast steel. Incorrect allowance was made for shrinking, the tyres were heated far too high for shrinkage, unsuitable modes of fixing the tyres were used, &c. So, on this field also, reverses came, to which, however, Krupp was already accustomed, whenever he undertook to introduce a new article. Trials had to be made in many and various ways, and sometimes the works were led into a wrong road. Thus, in 1856, a great many tyres were made of a milder steel, in order to meet complaints that the steel was too brittle. The consequence was, that now complaints came that the steel was too soft, and wore away too quickly, so that the higher price of cast-steel tyres no longer seemed justified. It took a long time before the right medium between hardness and tenacity was found. In the face of such difficulties, the merit of those companies and engineers who first showed confidence and intelligent interest in the innovation, deserves to be ranked all the higher. Not only did they help Krupp by their splendid testimonials to get over the mishaps incidental to the new work, but through their support he was able to carry out all those costly extensions of the hammers and shops, necessary to enable him to produce en masse and at paying prices. Up to January 1857, the total of orders received for weldless tyres was 3000 pieces. A third of these orders were from the Cologne-Minden company, a third from Austrian companies, and the remainder from German and foreign companies who had mostly ordered small lots. In 1855 French technical men had their attention drawn to the new invention at the Paris Exhibition, and became much interested in it. Owing to the hardness and smoothness of the tyre face, it was doubted at first, whether the cast steel would cause sufficient friction to hold them on the rails on steep inclines. Now Austria sent to the Exhibition the locomotive engine "Wien-Raab", fitted with Krupp's cast-steel tyres, and director Hasswell of the Vienna-Raab company, gave excellent testimony to the conduct of the tyres on the journey over the Semmering, so this prejudice too, could be considered as overcome. Austrian railway engineers spoke to Krupp of their intention of demanding the exclusive use of cast-steel tyres for locomotives, throughout the Austrian Monarchy, in the interest of the security of the service. The well known Austrian metallurgist Tunner ascribed to Alfred Krupp the merit, not only of having spread the reputation and use of cast steel for engineering purposes, and of its production in masses, but of being the real inventor of it. In 1856, similar tendencies to those in Austria seemed already to be gaining ground among the Saxon and Bavarian State Railways. The Bavarian railway testified that Krupp's cast-steel tyres had five to six times the duration of those formerly used. It was decided that Krupp tyres should be used exclusively for locomotives in Bavaria, and the equipment completed by the year 1862.

The high price of cast-steel tyres still formed an obstacle to their universal adoption, and Krupp was not yet in a position to work cheaply. The erection and equipment of the shops, the hammers, the puddling plant, and rolling mills had enormously increased his liabilities. The machining, which had to be done with extreme care, was complicated and expensive, and not before the middle of the 'sixties could the working process be simplified, whereas the cast steel factory at Bochum, the "Bochumer Verein für Gussstahlfabrikation", had begun, in 1856, to introduce cheap tyres which had been produced as castings, with subsequent rolling, but which were not forged. In consequence of their hardness, they were very resisting to wear and tear. The technical papers spoke of them in as high terms as of Krupp's tyres, they therefore soon found a large sale. Krupp who had made a trial with this mode of production in 1851, warned buyers to be cautious, and advised them not to look upon the good results obtained at first as a standard for the results in the long run. Disappointments were sure to occur, steel castings could not under any conditions compare with cast-steel forgings. For those days Krupp's opinion was right, and what he predicted came true; the value and importance of steel castings developed on another line. In the meantime, however, the Bochum process was a serious competition for Krupp. From another quarter also, cast-steel tyres made after an English invention of Jackson, appeared on the market, and were offered at 25 to 30 per cent cheaper in Germany than Krupp's tyres. This created a rather critical situation at a conjuncture when the capital invested in the works far exceeded the personal means of Sölling and Krupp, and when the existence of the establishment depended, so to speak, on a sufficiently high return of interest on the investment, and it will be easily understood that Krupp's friends and fellowworkers looked into the future with serious apprehensions. Sölling besought his friend at length to abandon his new plans, and to think of a quiet and safe return of profit:—"You exert yourself year out, year in, and have nothing but worries and cares, so that you are getting gray and old. What is the good of this vast establishment, and the great number of workmen, if with every new brick you lay, and with every new hand you put on, you add to your worries, and get yourself more and more deeply involved. Do begin at last to reap the fruits of your exertions and hard work, for it seems to me, the time has come that you should." Krupp's attitude of strictly adhering to fixed prices was not approved of either by his collaborators. His agents in Germany, England, France and Austria, by a unanimous appeal to him, insisted that only a considerable reduction of price could turn the scale in favour of forged seamless cast-steel tyres, and so procure sufficient work for all the new installations of his establishment. Alfred Krupp at first resisted, although he was at that time seriously depressed by the gloomy outlook for his works. He wanted to conquer the market, not by underbidding, but by the quality of his products. He declared it to be a grave mistake in principle, and even dangerous, to hunt for orders by reducing the prices during a depression of trade. The injury done to the reputation of an establishment would far exceed the advantages gained for the moment. He nevertheless submitted to a certain reduction of price for orders of considerable importance. In the end he proved to be right in his assertion and confidence, that a good thing must succeed in the end, even though it be slowly. On this occasion again, as he had so often done in the day of small things, he put his whole energy for the good of his enterprise to work, he tried personally to convince people, where doubts still existed, and, in the summer of 1857, he succeeded in getting the biggest order for tyres that had so far been given:—1500 pieces for the Bavarian State railway. Several orders followed in the autumn, in particular large orders from Austrian railway companies. With an output of 4000 tyres, the year 1857 marked for the time the maximum of production, although there were already signs of a reaction which naturally set in with the craze for enterprises and shares during the 'fifties. Krupp, however, since good orders also came in for other branches of manufacture, relied on a speedy improvement of the market, and in order to avoid the dismissal of workmen, had a great number of tyres, to the value of several hundred thousand Talers, manufactured on stock. But he was mistaken this time, the two following years did not bring the hoped-for improvement, and it was very difficult to find constant employment for all the workmen, whose number had risen to 1000 by 1857. In order to facilitate the introduction of his tyres, and to strengthen the conviction of their superiority, he offered in case of new orders, to take old, worn-out cast-steel tyres in exchange at a fairly high price. Many companies availed themselves of this offer, others thought it more profitable, to work the old tyres into tool steel themselves. Alfred Krupp's troubles were still further increased by Sölling's sudden death, which took place in January 1859. He had been to him, for fifteen years, a faithful friend and a great help. Notwithstanding, he now undertook the erection of a new shop, which he had already considered necessary in 1856, but which had been postponed at Sölling's instigation, that is, the erection of a second engineering shop. As the shop built in 1852 had for some time past been constantly full up, Krupp necessarily feared that, when business improved again, he would be unable to meet the demand. But besides, it was his old maxim to utilise periods of stagnation in business for strengthening the productive power of his works, and securing employment and wages for his workmen by the erection of buildings or the manufacture of machine tools in his own establishment. The erection of the hammer "Fritz", begun in 1859, was also the outcome of such deliberations. In the meantime, Krupp left nothing untried to get in more orders, he made an application to the Minister of Commerce for work from the Prussian State railways, the supply for which so far did not make up one half per cent of the total output. He offered extremely favourable conditions in order to get rid of his big stock of half-finished tyres, but without success. Notwithstanding this he did not give up all hopes that a universal approbation of his seamless tyres would eventually repay him for all he had sacrificed to them. He therefore applied in 1859 to the Government requesting that his patent, granted in 1853 for a comparatively short period only, should be prolonged by ten years. This was refused, as a similar request on the part of the Bochumer Verein had been a short time before. The Liberal Ministries of those days advocated the theory of free competition of economic forces, and it was considered to be for the common good, that the fruit of individual exertion should, as soon as possible, be turned to the benefit of the community at large. The conviction that the exaggeration of this principle, on the contrary, was more liable to check than to promote individual energy and bold enterprise, only recovered ground later on. To Krupp this refusal was a heavy blow, so much the more so, as in 1860 orders for tyres began to show a distinct upward tendency, which opened the most hopeful prospects for the immediate future. The annual output rose to three times that of previous years. And at this conjuncture Krupp had to fear that, as his Prussian patent expired in March 1861, he would have to forfeit the hoped-for and abundant fruit of his invention. In this precarious situation Alfred Krupp for the first time applied to the Prince-Regent of Prussia by a personal petition on the 8th of March 1860. This Prince had already shown an interest in the Krupp works by a visit in 1853, and in 1859 had manifested his confidence in cast steel by ordering 300 cannon tubes. In his petition Krupp called attention to what he had so far done, and to the sacrifices he had made for the introduction of the cast-steel gun, the expenses of which he had been obliged to pay out of the profits made on other branches of manufacture. He brought to the Prince-Regent's notice the fact that the State railway had hitherto shown very little interest in his products, and he petitioned for the sovereign's personal interference by way of exception. His confidence was fully rewarded. Acknowledging the fact of "the extraordinary smallness of Krupp's share" in the orders given by the State railways, the Prince-Regent decreed on the 25th of April 1860:—"In recognition of the patriotic feeling, that had on many occasions been manifested by the Commerzienrath Alfred Krupp at Essen, in particular by rejecting orders for guns sent to him by foreign countries, which held out the prospect of considerable gain, and in consideration of the circumstances alleged by him, I ordain that the patent which was granted him on cast-steel tyres without welding seams, on the 21st of March 1853, for a period of 8 years, shall be prolonged by another period of seven years . . . . . . ".

So the patent was now granted for the longest legally permissible period of fifteen years, and Krupp could go about his work with fresh courage. The manufacture of tyres, now perfectly developed and capable of being carried on profitably, became for many years the life-giving source for the Cast Steel Works; years, during which the manufacture of guns imposed on them the heaviest sacrifices in the way of experiments and new installations. But such, it will be remembered, had been Krupp's maxim all along; to renounce the fruits of one success painfully attained by hard work and sorrow, in favour of the next step forward. The year 1865 brought the fulfilment of Alfred Krupp's wish, which ten years ago he had formed after the first success of his newly completed tyre-rolling mill; to be able to produce 20,000 to 25,000 tyres annually. The average annual output for the next ten years was 32,000 tyres. Until the year 1866, the mill, which had been started in 1856, had been able to respond to all requirements. Now a second double mill of the same design was added and put up in a spacious new shop. The old mill continued to work till the beginning of the 'seventies, when it had to cede its place to an extension of the hammer works. This new mill also had two independent frames, one of which is still in use, while the other was pulled down in 1877, to be supplanted by an English Galloway mill of a larger yield of produce. The rolling out of tyres has by degrees been so improved that now the whole process from rough rolling to final centering can be accomplished in one heat. As the demand for weldless tyres kept on increasing, a third mill for small-sized tyres, also English, was put up in 1908.

The process of rough-forging tyres under the steam hammer has also passed through several phases. Its original form was as follows:—heavy square-sectioned steel bars, obtained by forging, were upset at the ends, so as to thicken them; the centres of these heads were then pierced, and the interval between them cut through with a circular saw, the slot so obtained was widened, and a circular shape finally obtained by forging. This process was carried out until 1864, when the operation of piercing the heads and obtaining the slit by a saw was substituted, following a suggestion of the foreman-smith Pelz, by a process by which the slit in the bar was obtained under the hammer, while the steel was red hot. In this operation a strip of steel one inch wide was punched out of the middle of the bar. This process was a great saving of time. Next, the old helve hammers, which hitherto had mostly performed the work of cutting off the ingots and of rough-forging them were gradually abandoned for steam hammers which yielded twice the work with less outlay. The subsequent operations of widening out the split bars and forging them into circular shape, was done as before. The tyre manufacture remained at this phase for another ten years, it was not till the middle of the 'seventies that a new and fundamental change took place. The serious depression of industry dating from 1874, acted apparently as an incentive on all workshops, to compensate for the bad state of business by technical progress which would enable them to work with profit even though the prices had gone down very low, and thus to retain the lead. It was for such reasons that the new English mill was bought, which worked materially cheaper, and in those times, too, a new working process was developed which had already been recommended by Krupp many years back, and which has remained in practice to this day. The ingots were no longer stretched and forged into bars of a square section, but, on the contrary, they were upset, forged round, and divided into a number of discs. Through the centre of each a hole was pierced under a 110-hundredweight hammer, this was done by placing a slightly tapering mandril on the disc, and by driving it right through by a rapid succession of strokes while the disc was red-hot. A small disc of 20 centimeters in diameter was punched out of the centre by this process. In the same heat still, the ring thus obtained was widened out by forging, and at the same time provided with an embryo flange; after which the rough forging was completed on a mandril after a second heating. Practise had thus returned to a method, by which Alfred Krupp, forty years before, had made his first rings for rolls. Considering the thickness and size of the discs in question, the piercing seems a rather violent operation, which, however, the fibrous texture of the steel can very well stand. These forged rings need only be reheated once more, which is done in a regenerative furnace at a steady temperature, after which they are finished on the mill in one operation.

The original advantage to Krupp arising from his patents on the manufacture of tyres, has long ceased to exist, the manufacture of weldless railway tyres became the common property of the steel industry forty years ago. Nor does crucible steel occupy any longer that exclusive position as a material for railway tyres. Although it is to this day preferred for locomotive tyres, it has had to give way to some extent, in the manufacture of tyres on a large scale, to open-hearth steel, which is cheaper yet perfectly adequate. But even under these modified conditions, the manufacture of tyres in the Cast Steel Works has gone on rising steadily. During the 'eighties it amounted to an average annual output of 56,000, during the 'nineties of 68,000, and during the last decade of 87,000. More than 2,750,000 tyres have proceeded from the rolling mills of the Cast Steel Works since the invention of weldless cast-steel tyres, and have contributed to make Krupp's produce famous in all parts of he world.

When Alfred Krupp took up the manufacture of railway axles and later on of weldless railway tyres, it was a step which needs must lead him to new enterprises outside the path he had hitherto pursued. The manufacture of wheels and of mounted wheels on axles was one of these, a branch, besides, upon which he did not look with much favour, but which he saw no way of avoiding without doing serious harm to the sale of his axles and tyres. But as Krupp always was desirous of developing whatever he undertook on the widest scale, and to its highest technical perfection, the Cast Steel Works became, in this line also, one of the biggest enterprises, and Krupp himself one of the most successful designers and makers of railway wheels.

As early as the 'fifties Krupp was forced to consider the making of railway wheels, because many companies could not make any use of axles and tyres, if they could not get the entire sets of wheels, or at least the wheels with the tyres shrunk on. Nearly all the public tenders advertised for by railway companies mentioned finished sets of wheels, and orders for single axles and tyres were an exception, unless they were given by locomotive-engine and carriage-building firms, or by companies who had their own operative departments. Even for the first big order given by the Cologne-Minden company for railway tyres, it was understood, that the wheels also should be furnished, and Krupp had great difficulty in getting the concession, to furnish cast-iron, instead of wrought-iron spoke wheels. These he was able to cast in the iron foundry which he had just started. Thus in 1854 the manufacture of wheels was started at the Cast Steel Works. These wheels were rather heavy at first, but perfectly original in design. They were of the disc type, and proved very durable even after long use. Krupp took out patents for them in England and France. The disc of the wheel represented in section an undulating line, and in consequence of this shape offered great resistance to vertical and lateral strain. Their general adoption was discouraged by their great weight and by the prejudice then existing against cast-iron wheels in general, which was only overcome eventually by the chilled cast-iron wheels of Gruson and of Ganz at Buda-Pesth.

In 1856 Krupp announced his intention of changing the mode of manufacture of wheels, he was even contemplating the making of spoke wheels, although he considered disc wheels to have much more resisting power, and to afford a much better support for the tyre. It so happened that numerous experiments were made in those days in pressing and rolling wrought-iron wheels, and Krupp too tried his hand at this. By means of a rolling process, rather clumsy it must be admitted, he succeeded in making a disc wheel out of puddled steel with boss and rim all in one piece, much lighter than the cast-iron one, and which in combination with Krupp's cast-steel tyre seemed to promise fair success. From puddled-steel bars placed crosswise in layers one above the other, a block was welded, on which the boss was obtained by stamping it with a die, the remainder of the metal was then rolled out into a disc between horizontal rolls. By means of a press on the Daelen system, this disc was turned up along its circumference, so that a rim was produced on to which the tyre could be shrunk. In December 1858, Krupp gave notice of this invention by a circular which he sent out to all the railway administrations at home and abroad. A temporary plant was put up for the manufacture of such wheels, but once more the result did not answer the expectations. Most likely the working process was too complicated and too expensive, so that the wheel could not be sold profitably. Yet the first complete sets of wheels that came out of the Cast Steel Works comprised such disc wheels. Six sets of wheels for the Imperial Russian railway from St. Petersburg to Czarskoye-Selo, the summer residence of the Czar, were among the first orders, and were followed by others from Russia. Also the Rhenish railway company, and the Prussian Eastern railway have, from 1859 onward, bought such sets with cast-steel axles and cast-steel tyres. These first mounted wheels were machined in the mechanical workshop No. I, where between 1855 and 1856, six lathes had been put up for that purpose. An hydraulic press for fixing the wheels on the axles, Krupp had already built himself in 1855, with the aid of Wöhlert's engineering works at Berlin. The first lathes for machining wheels mounted on axles were ordered from Munich, where the machine-tool industry was long established and had developed to high perfection. The demand for disc wheels, however, remained as small as before, most railways preferring the double-spoke wheel, which was then universally adopted. Krupp could not make up his mind to take up the manufacture of these wheels, which again would have demanded new plant. Besides, at the time, he was too much occupied by other problems. Therefore towards 1860 he joined Wöhlert, who was fully equipped with plant for the manufacture of wheels and wheels mounted on axles, and who executed large orders for German railway companies in this line. The arrangement was this, that Krupp henceforth should hand over any orders for mounted wheels to Wöhlert, furnishing himself the cast-steel axles and tyres, whereas Wöhlert should make the wheel centres, and do the shrinking-on and the machining. In return Wöhlert who had always been a partisan of cast steel, did his best that the wheels and mounted wheels, for which he received orders, should get Krupp cast-steel axles and tyres. This agreement remained in force until the second half of the 'sixties; in the meantime Krupp had been compelled by circumstances to contemplate the manufacture of wheels and sets of wheels on a large scale, himself; the consequence being, that between 1864 and 1865, apart from the engineering workshops, the number of which had already had risen to four, a separate turning shop, exclusively devoted to the finishing of mounted wheels on axles, was erected.

A short time before, Krupp had also realised a considerable progress in the manufacturing of wheels, following the example of the Bochum cast steel factory, which had taken up making solid railroad wheels with the tread in one single piece, by steel casting. Krupp had adopted this process since 1863, and after many trials, partly with crucible steel and partly with Bessemer steel, he had finally attained brilliant success. On the premises of the works to the south of the Mülheimer Chaussee, which was then not yet built over, a big new steel foundry, mainly intended for steel castings, was erected in 1864. Casting was done here, as it had been in the older foundry, from the crucibles direct and not from ladles. That same year, the first mounted sets with the so-called cast-steel disc wheels were furnished, and after 1865, they found a very large market. In consequence of their hardness and cheapness, Krupp soon applied the same method to making big wheels for locomotives, and in 1867, exhibited at Paris a locomotive crank axle with cast-steel disc wheels of 1·88 meter diameter mounted on it. On the recommendation of the Prussian authorities, these were awarded a prize, but as many railway companies adhered to the old approved system of wrought-iron wheels, Krupp, in 1866, also took up the manufacture of double-spoke wheels, which consisted of a cast-iron boss with spokes and rim made of flat iron bars welded together. The first order for such wheels mounted on axles was executed for the Berlin-Anhalt railway in 1866. At first only small wagon wheels were made in this way, but, after 1867, locomotive wheels were also made by the same process. Thus the manufacture of mounted wheels on axles assumed ever-growing dimensions, so that, in 1870, a second workshop for mounted wheels on axles had to be put up; the annual production amounted to from 6000 to 7000 sets, and was still growing. The rapid extension of railways during the prosperous period after the Franco-Prussian war, greatly promoted this development, and in 1872, it even became necessary to build a third, much larger workshop for the same purpose. It may be mentioned that, at that time, the engineering shops, the turning shops for axles and wheels, and the gun shops still constituted one group under one common head, and a good deal of preparatory work for the sets of wheels, such as the turning of axles and tyres, &c. was still done in the mechanical and gun shops.

But steel disc wheels did not in the end prove able to resist the ever growing strain on railway material; they certainly were cheap, but they did not guarantee the safety, nor had they the durability of wheels with cast-steel tyres shrunk on. Especially when exposed to the effects of the brake, they quickly deteriorated, so that in 1886, their use on Prussian railways was forbidden under carriages fitted with brakes. Only wheels of welded iron with cast-steel tyres were admissible for this purpose. Krupp had, many years before, made improvements to meet this emergency. After his experiments with plate disc wheels had not been attended by any lasting success, he obtained a better result in 1875, with his coiled disc wheel, which was obtained by coiling a tape-like iron bar round a welded iron boss and welding the whole together under the steam hammer. These coiled disc wheels, which were patented in many countries, were far superior to any preceding product; under the severest tests they proved almost indestructible, so that, in combination with the Krupp cast-steel tyre, they conquered almost the whole of the world. A specimen figures as an emblem on Alfred Krupp's monument at the entrance of the works, as one of the most remarkable and successful products of the works. This invention, however, took place at a peculiarly unfavourable time. In consequence of the commercial crisis of 1874, orders became so scarce that the older wheel-turning shops had, for several years, to cease working altogether, and even the new shop for mounted wheels was affected by the want of employment. But in this, as in former cases, and in other branches of industry, the low condition of trade and industry quickened endeavours to compensate for the cheapness of prices by technical improvements and economical working processes, and so, after all, the depression was attended by permanent beneficial effects. In those days, for instance, among other things, a successful attempt was made to economise time and cost of transport by a division of labour and by uniting the localities of successive operations. In course of time, the entire manufacture of wheels and wheels mounted on axles was combined in shop No. III, originally erected for this purpose and now enlarged, while the other shops were turned to other uses.

In later years the manufacture of railway wheels at the Krupp works was extended by fundamental improvements on two other occasions. The production of steel wheel centres by castings received a new impetus, when, in 1886, Krupp acquired the steel works of Asthöwer at Annen. These works had gained special distinction for steel castings, and had also produced by this method driving wheels and coupled wheels for locomotive engines, which henceforth were furnished in combination with Krupp's cast-steel tyres and axles. These cast wheels were so well received by the railway companies, that the old process of making them from welded iron, ceased there altogether. A few years later the casting of heavy wheels was also taken up at Essen, after which the manufacture of finished sets of wheels for locomotive engines developed enormously during the 'nineties. The consequence was the setting up of a number of new machine tools, and another extension of the workshops appropriated to this kind of work. A second departure of marked and important progress in recent years was the introduction of a new process of manufacture of ingot-iron disc wheels, which now have taken the place of the coiled wheel. The entire wheel, that is boss, disk and rim, is obtained by a simplified process of pressing and rolling from one block of ingot iron, and while of low price, it presents an extraordinary safety against cracking or fracturing. In technical and economical respects this process is just as much superior to the manufacture of rolled disc wheels alluded to above, as the present mode of rolling tyres is to the first forging of them. From an historical point of view, however, it is most interesting to note, that Krupp attempted the manufacture of rolled disc wheels 50 years before the process was practically applied, and that no doubt, he obtained a certain technical result at the time.

The products described above have not only marked out the road which the development of the Cast Steel Works had to follow during the 'fifties and 'sixties, but they have also contributed largely to the development of railroads. The increase in speed and in the loads transported, the growth of every kind of traffic after 1850, involved of necessity a far greater strain on railway material, and consequently a demand for higher resistance, if the safety of service were not to be overlooked. In applying cast steel to all essential parts of the rolling stock, and by fighting with unabating energy against the obstacles that opposed its adoption, Krupp, at the right time, attacked a problem, the solution of which was of vital importance to the growing traffic. His final success therefore was great beyond bounds, though the struggle was hard by which he attained it. The enormous expansion of railroads during the 'fifties and 'sixties naturally paved the way for this success. The mileage of railways in Germany amounted in 1850 to 5800 kilometers, in 1865 to 13,800 kilometers; 300 locomotive engines were running on German railroads in 1854, as against 1500 in 1864, on Prussian railroads alone, and 6000 in England. In France the number of railway passengers rose from 22,000,000 to 65,000,000 between 1852 and 1862. Such times were naturally well suited to the introduction of new products in the way of railway material. The permanent way also underwent modifications as the traffic grew. The original cast-iron rails were superseded by rolled welded-iron rails, and in the 'fifties an attempt was made to remedy the rapid wear of rails by the use of a puddled-steel head. For the superstructure, however, the age of steel only dawned after the invention of the Bessemer process. Here Krupp again was the man to recognise at once the needs of the times, and to find the proper means of supplying them. He was the first to introduce the Bessemer process into Germany in 1862, and to take up the manufacture of steel rails a few years later. Thus, here too, he secured for himself a place in the first rank, and succeeded in developing his enterprise from the limited circle of a manufacture of specialities in cast-steel products into works appealing to a world-wide market of steel industry.

## THE CAST-STEEL GUN.

Krupp's cast-steel gun is, among all the products of the Cast Steel Works, that which has most widely and most lastingly spread the fame of its maker. The world has called Alfred Krupp the "Gun King", and the uninitiated are wont to look upon the Krupp works solely as a gun factory, although their entire output was, for more than forty years, and to its greater portion to this day still is devoted to peaceful ends. It was in the field of industrial work for peaceful objects that the Cast Steel Works sprang up and first took root. On this soil, that technical basis was laid, that experience and those resources were matured, which had to precede the application of cast steel to firearms, that only assumed important dimensions during the 'sixties.

The first evidence of Krupp's interest in the question of making firearms of cast steel dates back to the year 1836, and is connected with gun barrels. About this time Hermann Krupp wrote to his brother from Munich, that a dealer in small arms would like to have two cast-steel gun barrels, as the iron barrels, used in target-shooting easily became rough in the bore.—The gun barrels then in use, were made of flat wrought-iron bars, rolled so that the longitudinal edges met which were then welded together.—The order was not executed at the time, because the Cast Steel Works were not equipped with tools to bore out the barrels. Besides, Krupp's time and interest was fully taken up by other things, more particularly by the introduction of his rolling mill, the erection of the first steam engine and the new buildings required for them. Alfred Krupp only recurred to the matter about the beginning of the 'forties, when the sale of the earlier products of the works had considerably slackened, and it is remarkable, that his project from very the first aimed beyond the rifle barrel, immediately at the cast-steel cannon. In 1843, he came in touch with a Lieutenant von Donat, then on a special commission at the rifle works at Saarn, near Mülheim-on-the-Ruhr, and sent him a specimen of a rifle barrel, solid forged of the mildest cast steel, for him to examine. He accompanied it by a letter in which he said:——".... although I do not in the least calculate that the State will decide on a change in the manufacture of guns, and though I look upon this specimen only as a sample on a small scale of the excellent qualities of this material for cannons, yet I will make an attempt, as soon as possible, to forge such rifle barrels at once as hollow tubes——I hope that you will shortly have a more favourable opinion of my plan to make cannons of the cast steel mentioned...." The attempt to forge hollow gun-barrels all in one piece, without welding seam, was perfectly successful; Alfred Krupp himself did the forging, and he was probably the first who ever produced seamless tubes made of steel. The process resembles, in a way, that employed for weldless cast-steel rings for tinsel and reed rolls, but was of course much more difficult on account of the greater length of gun barrels. Alfred Krupp himself afterwards gave a description of it:—"Thirty-five years ago, I forged hollow gun barrels after my own method; first a hole was pierced through a piece of steel, and then it was stretched by forging it on a cold mandrel. The hole of the barrel, rough-forged in this way, was filled up by pouring molten steel into it. Then the barrel was reheated and again stretched on the anvil, and while still warm the core was pulled out. Finally the barrel was finished by forging on a cold mandrel. It was very interesting work, and the barrels made of mildest steel were of unusually great tenacity; and so much is quite certain, if anyone wished to make particularly excellent barrels, he would have to have them made in this way." The tests to which such cast steel barrels were submitted, gave very favourable results. Krupp then applied to the Army Authorities, in order to gain their approval of the new weapon. The moment seemed propitious. Prussia had, in 1841, adopted the Dreyse needle gun, and France had been for some time experimenting with rifled guns. In both countries, therefore, a large demand for barrels seemed imminent. On the 1st of March 1844, Krupp wrote personally to the Prussian Minister of War, accompanying his letter by two cast-steel barrels. The letter contained an offer to place a cast-steel cannon tube at the disposal of the Ministry of War. The opening words of the letter are interesting. "Well aware of, and with a thorough knowledge of the essential qualities that a material should possess out of which cannons can be made, I have experimented, and examined the question, if instead of wrought iron for gun barrels and bronze for cannons, one single metal suitable for both uses could be produced. I have succeeded in bringing out a cast steel endowed with the qualities of strength, purity and ductility in a higher degree than any other metal". The gun barrels proved a great disappointment to Krupp. The Ministry of War refused to test them, and sent them back, remarking that no use could be made of them, as the present rifle barrels answered all the requirements that could be fairly demanded of them, and that they left hardly anything to be desired. It was not long, however, before the cast-steel gun barrel received due consideration, when during the second half of the 'forties higher ballistic capacities were demanded of the needle gun, which iron barrels could not afford, being unable to stand the higher strain. In 1847 therefore Dreyse ordered from Krupp solid bars of cast steel low in carbon; he did not require to have them already hollow-forged, but drilled them himself. The result of tests made with such barrels was, that from the beginning of the 'fifties, soldiers rifles in Prussia were only made of cast steel. The well-earned profit resulting from the introduction of cast steel into the manufacture of rifles was not, however, reaped by Krupp. It fell to his competitors who drilled the bars at once, whereas Krupp adhered too long to the more difficult process of hollow-forging. Krupp, later on, likewise adopted the drilling process, and at the present day the Krupp steel works at Annen furnish a part of the gun barrels of the Prussian army. Still, it seems, that Krupp did not attribute much importance to the manufacture of rifle barrels, to him they were only a precursor and a sample on a small scale for the larger experiments that were to follow, and which aimed at the employment of cast steel for cannon tubes.

Krupp's offer to the Prussian Ministry of War to place a cast-steel cannon tube at their disposal for trial, was accepted. The answer of the General War Department of the 22nd of April 1844, ran in these terms:——"you are hereby informed that the undersigned Department does not feel disinclined to grant the cost of trials with a view to the manufacture of a cannon of cast steel in the way you have proposed, on the supposition, however, that the expenditure does not run to too high a figure. You will therefore carefully consider, how the arrangements can be made in the most economical way, without detriment, however, to their result." The gun tube was long in getting finished, and could only be sent to Berlin in the summer of 1847. It was a 3-pounder tube of 6·5 centimeter bore, composed of a cast-steel inner tube with a cast-iron jacket round it, provided with trunnions. The manufacture of massive cast-steel tubes, with trunnions forged on, only succeeded much later. The testing of this first cannon tube of cast steel was terminated in June 1849; it had comprised accuracy of fire, wear and long life, and finished up with a bursting test, in which the tube was destroyed. The report of the Experimental Artillery Committee on these trials says:—"The results of the tests, which proved so favourable for the strength of the tube, give evidence that the cast steel of which it is made, presents a raw material which for toughness and hardness excels all other pure or alloyed metals hitherto known, that have been employed for cannon tubes . . . Yet however advantageous the use of cast steel for cannon tubes may appear, insurmountable obstacles present themselves in its costliness, . . . so that there seems no chance left for an eventual adoption of cast steel, more particularly for big calibers. There is another circumstance in its disfavour, that the value of cast steel of old discarded cannons is only very small. Finally, it may be seem doubtful whether the manufacture, especially of heavy cannons, in case it should become possible in future, could be made uniform to such a degree that the results would always prove the same. . . . But as there is hardly any necessity for an improvement of our heavy ordnance, especially of our field guns; and since all that seems desirable for the present is, that our heavy bronze tubes should have a longer life, and the iron ones should be made more reliable as to their strength, yet, even though the price of the metal could be considerably reduced, the costs for heavy tubes would remain far too high, the manufacture and application of cast steel for artillery, however useful it may otherwise appear, seems for the present destined to remain merely an object of general interest." The General War Department passed this report on to Krupp, adding:—"We can but agree with the considerations stated herein, and cannot encourage you to continue your experiments, unless you foresee that you will succeed in removing the obstacle to the introduction of such gun tubes which consists in their high cost." The result of the testing of this first cast-steel cannon has not been published. Alfred Krupp saw in the answer of the military authorities but the one acknowledged fact, that his cast steel was superior to cast iron and bronze hitherto in use as gun metals. He was more than ever convinced that he was on the right track, and he was sure that he would succeed even in the manufacture of big tubes of a uniform nature. It was not scientific research and experiment that filled him with this conviction, for in those days there were no chemical and physical methods of testing and examining steel, such as are in practice now. Alfred Krupp's conviction was rather founded on his long experience, derived from practical manufacture. The works could now command a process perfectly reliable and uniform in its results, and by which they were able to endow cast steel with certain definite properties, corresponding to the use for which it was destined. On this firm basis of the absolute superiority of his cast steel as regards strength, Alfred Krupp's keen foresight beheld the wide domain that opened out for it with its application for firearms.

Since immediate results were not to be expected in Prussia, Alfred Krupp tried in other countries to interest the military circles in his gun. He began by taking out a patent in England and France both for the employment of cast steel for guns and for the design of his compound tubes. For the International Exhibition of London in 1851, he had a 6-pounder tube, placed on a field carriage, made after the pattern of the 3-pounder gun tube tested in Berlin. The splendid workmanship of this gun created quite a sensation, and the official report of the Prussian department called it a real work of art. In the following year, King Frederic William IV, at the request of Alfred Krupp, declared himself willing to accept this gun as a present. Before it was sent to Potsdam, Krupp had a few little things done to the gun carriage at the ordnance workshop at Deutz. When, in April 1852, the Prince of Prussia, afterwards the Emperor William I, saw it there, he said to his attendants:—"I want to make the acquaintance of this genius, of this Mr. Krupp". It must, no doubt, be attributed to this incident, that the Prince, when he happened to be on a military tour of inspection, visited the Krupp works for the first time, on the 16th of June 1853. After the gun had been at the Royal Castle at Potsdam for some time, the King passed it on, about the end of 1852, to the Arsenal at Berlin:—"to be carefully preserved", and there it is now. Of the two first guns made at the Cast Steel Works, it is the only one still extant. In the meantime, an attempt had been made to forge a gun, together with its trunnions, from one massive block, in order to raise its ballistic capacities. The experiment succeeded in 1854, and from that time forward, first the small ones, and later on also the big guns, were made as massive forgings, till from 1865 to 1867, the hoop-and-jacket design brought a new increase of the power of cast-steel guns. The first solid forged cast-steel gun tube, a 6-pounder, was made in 1854 for the International German Industrial Exhibition at Munich. Both the London and Munich Exhibitions largely contributed to attract the attention of wider circles to Krupp's cast-steel gun, and a few trial guns were ordered during the following year by German and foreign states. Soon the results of such trials began to be published, and in particular no small sensation was created by a publication of Lieutenant-colonel Orges, of the year 1855, on the results of a bursting proof with a 12-pounder cast-steel tube furnished by Krupp to Brunswick. The gun sent to Munich was subjected to a test of 2000 rounds in 1856, and later on, after being transformed into a rifled muzzle-loader on the system of curved-sectioned grooves, 239 more rounds were fired from it with the object of bursting it. But it came out uninjured of all these tests, and was finally, in 1867, broken up under the tup of a hammer at the Augsburg Engineering Works, in order to compare the quality of Krupp's cast steel with that of other works. The report of these final tests mentioned in very high terms the excellent properties, the tenacity, strength and homogeneity of Krupp's cast steel. From a 12-pounder shell gun sent by Krupp to the Paris Exhibition in 1855, 3000 rounds were fired at Vincennes, after which no wear of the bore could be observed. This result induced the French Minister of War, to order two more guns of the same type from Krupp, in order to ascertain if the result of the one gun was not due to an exceptional and accidental success of manufacture. Both guns were tested in 1857 at Vincennes with the same excellent result. After that the French Government tried to enter into negociations with Alfred Krupp about the establishment of cast steel works in France, the matter, however, fell through, because of Krupp's unwillingness. In Russia also Krupp's guns, furnished to that country from 1856 to 1857,—a 12-pounder tube and a 60-pounder jacketed tube,—were much approved of. General von Todleben, the famous defender of Sebastopol, wrote about these guns to Alfred Krupp:—"The guns furnished by you to the Russian Government, namely one 12-pounder, and one 60-pounder with cast-iron jacket, have been submitted to firing tests. The 12-pounder has stood 4000 full-charge rounds, without showing the least damage to the bore. This gun has been placed in the Ordnance Museum as a curiosity. From the 60-pounder so far, 900 rounds have been fired, with the same result. The trials will be continued." The 12-pounder gun tube on which the above data have been engraved, is at present in the Artillery Museum of the Fortress of St. Peter and St. Paul in St. Petersburg. In the course of the 'fifties, guns of big calibre, on the jacket design, were delivered to Russia, England and Holland. In 1859, the King of Prussia accepted from Krupp a 68-pounder bomb gun of this type, such as were then used on board ships, as a proof of the productive capabilities of his works. The King presented it to the Royal Ship Yard at Dantzic. When these yards ceased to exist in 1872, the gun was returned to the Cast Steel Works where it is now preserved in their collection.

The first big order for guns came from Egypt. The attention of the Egyptian government had been drawn to Krupp's guns by the trials in France, and they ordered, during the years 1856 to 1859, twenty-four 12-pounder and twelve 24-pounder muzzle loaders. More important for Krupp was the awakening interest in Prussia for the cast-steel gun. Here, after protracted trials with cast-iron 12-cm and 15-cm breech-loading guns, the breech-loading system for field-guns had been finally adopted in 1855. The opinion gaining ground, that bronze guns wore out too quickly, and that cast-iron guns were too heavy, it was decided after the trials at Brunswick, to adopt cast steel. About the end of 1855, two cast-steel blocks for 6-pounder gun tubes were ordered from Krupp, they were finished in the workshops of the 'Gun Foundry' at Spandau. The results obtained in the tests of these guns during the following years, turned the scale in favour of cast steel. In a book written in commemoration of the centenary of the Experimental Artillery Committee, and published in 1909, we read on this subject:—"In 1855, two 9-cm cast-steel tubes were ordered from Krupp. This order marks the change of a temporary connexion with this firm into a permanent one. The works have from that time forward proved loyal collaborators of the committee. The tests with the 9-cm cast-steel guns were so successful that in 1857, the committee could report that cast steel was the most suitable metal for long rifled guns, and for it could no other be substituted." By a royal decree of the 7th of May 1859, the rifled 6-pounder field gun of cast steel was adopted for Prussia, and it was ordained that 300 cast-steel blocks for gun-tubes should be ordered from Krupp.

The order was to be for 72 pieces only, at first, but the Prince-Regent at once changed it into the bigger one. The tubes were to be furnished drilled and turned in the rough, the workshops, however, at the Krupp works were not yet equipped for such work, and so with the exception of 23, only rough-forged blocks were delivered, which were partly finished at the Royal Gun Foundry at Spandau, and partly at the private works of Freund and Wöhlert at Berlin. During the next year, other important orders were received both from Prussia and other German states, as well as from abroad. Between 1861 and 1863 Belgium armed her field artillery with Krupp guns, which had to be furnished by the works ready for use. During the years 1863 to 1866, Russia ordered a number of guns, more especially big calibers of 21 and 24 centimeters, and also field-gun tubes of 8·7 and 10·7 centimeters.

The Prussian order of 300 guns, in the year 1859, constituted the first great success after the hard work of so many years. It was a success also, in so far as it freed Alfred Krupp from a state of mental depression, for in spite of all the brilliant results of trials, no orders had come in for a long time, and this had so disheartened him, that he was on the point of giving up the manufacture of guns altogether. So, in the beginning of 1859, he wrote to a Hanoverian officer:—"It is most likely that, after having paid dearly enough for the honour, I shall entirely give up the manufacture of such guns," and about the same time he says in a letter to Lieutenant-colonel Orges at Brunswick:—"The object of the gun, furnished for trial, was not permanently to establish a new branch of manufacture on a large scale, but to secure progress and gain recognition, which might be turned to account in the essential business of this work, which is the manufacture of objects for the peaceful pursuits of life". The instruction given to his Berlin agent was to this effect:—"You may call on the gentlemen at the War Department, but without in the least applying for their orders, on the contrary, you may explain to them my real views and incidentally mention the declaration which, some time ago, I definitely gave to the French Government, that I intend to stop the unremunerative manufacture of guns altogether, the object of the trial now being attained; and that I no longer think of accepting an order from France, since there is a possibility that the muzzles of these guns may one day be turned against Prussia. The low financial value that I set on the manufacture of guns could only be raised by orders of large numbers, say about 1000 guns, such orders would be worth accepting, in so far as they would furnish lasting employment for some longer period." A few months later followed the first big order from Prussia, which was the decisive turning point in the future evolution of the works in this field. It was likely now, that this success would attract other orders, and that finished guns would also be ordered to a considerable extent. The works, therefore, could not stop short at furnishing only cast-steel blocks for gun tubes. The next measure must necessarily be to equip the works for the manufacture of finished guns in large numbers. The first guns had been made in the mechanical workshop No. I, erected in 1852, in the upper story of which appliances had been put up in a limited way for this purpose, since 1855. The required machine tools Krupp had for the most part made himself, he had especially arranged a number of his old turning lathes for the machining of gun tubes. The drilling of the bore hole out of the hard cast-steel blocks was a difficult job, which at first met with occasional ill-success and loss. But Krupp utilised the experience thus gathered so well, that he was later on in a position to give valuable hints to the workshops of the Spandau Gun Foundry and the Berlin works, to whom the finishing of the cast-steel guns was entrusted, but to which they were not yet accustomed. Krupp's original tools were of course no good for any orders of importance. In 1859 therefore, a double gun-turning lathe, and a double milling machine for trunnions, and several grinding benches for guns were put up, and in 1860, an English boring machine for breech holes. In the same year also the erection of the first gun shop was begun, which was started in 1861, and in 1862 was already full up with work. It was here also that, besides the ample equipment with turning, drilling and milling benches, the first tools for rifling guns were put up, some of which were ordered complete, while others were built at the works. These rifling benches, which at first worked with one cutter only, cut the grooves into the bore in the direction from the muzzle to the breech; afterwards heads with several cutters were introduced, working the other way, that is from the breech to the muzzle, thus drawing out the metal. The seven portions of gun tubes with various samples of rifling, shown at the London Exhibition in 1862, were made in this shop. After Alfred Krupp had once made up his mind to furnish finished guns, he followed up the object with his usual energy. He calculated, that an equipment of fifteen turning lathes, twelve milling machines, and twenty-three drilling and rifling benches would be required, to finish on an average one field gun tube in a day of twelve hours' work. But the evolution of things forced him to go far beyond this first estimate. In 1863 the manufacture of big guns was undertaken, and this required another expansion of the appliances. In 1864, new hammer works were built, to forge blocks for gun tubes, and also a second gun shop of two bays was started, which could begin work already in 1865. In the same year a big fire broke out at the Cast Steel Works, which destroyed considerable portions of the gun shop No. I and the mechanical workshop No. III, besides valuable experimental material, and in particular a great number of precious models. This incident, which even in after years made Alfred Krupp shudder at the idea of the consequences it might have had, was the occasion of creating a permanent fire brigade, and issuing careful regulations for the control and the safe-guard of the works against danger from fire. In 1866, a viaduct, supported on iron columns was built between the gun-shops No. I & No. II, on which were placed the drawing and designing offices of the gun department, which in those days still formed one with the group of the engineering workshops. Here were the modest offices of the engineers Otto Beyer and Oscar Richter, who had come to Essen in 1857 and 1860 respectively. Both were greatly valued by Alfred Krupp, and both were very active in developing the engineering and gun shops. Speaking of Beyer, Richter, and Gross, who will be mentioned later on, Krupp said:—"With these three one may conquer the whole world." As the orders for guns rapidly multiplied, rising in 1864 to 817 pieces. and in 1866 even to 1562 pieces, gun shop No. II was not equal to the work, although it was effectively supported by the engineering shops. It had hardly been fully completed in 1866, when the building of a third gun shop was started, "exclusively for the construction of heavy guns". Work was begun here a few years later. Finally in August 1870, gun shop No. IV started work, it comprised a turning shop, an erecting hall and a shop for the shrinking-on of hoops and jackets, and was strictly closed to all but workers. Up to this time the shrinking-on operation had been carried out by temporary appliances in the central bay of the mechanical workshop No. IV, which was mainly destined for the erection of heavy pieces, and consequently was fitted with a correspondingly heavy travelling crane. Afterwards this shop also was entirely taken up by ordnance manufacture. The new shrinking-on shop, in the gun shop No. IV, was equipped with gas furnaces and perfect mechanical appliances, and in addition to the regular work for which it was intended, was also used for numerous new experiments. The pressing of the steel-plate sides for gun carriages and mounts was for a very long time also carried on in this shop. The erection of the gun shop No. IV terminated the building activity of the firm in this direction for many years.

Simultaneously with, and partly as a consequence of this rapid growth of the establishment, the evolution of the Cast Steel Works took a most important and decisive turn. Within a very short time considerable capital had been invested in new branches of manufacture, which only could be made profitable by securing large orders for guns. Such orders, however, especially from abroad, could only be looked forward to, if, besides the manufacture of gun tubes conforming to accompanying designs, Krupp was able to take the designing of guns into his own hands. This seemed the only way to a quick attainment of his object, and to a successful conquest of the difficulties and opposition standing in his way. For centuries gun tubes had been made of cast or wrought iron, or of bronze, the entire system of artillery was built up, as regards design and tactics, on this raw material, and the views connected with this subject had become firmly established. Now suddenly a new metal had appeared, a very expensive one into the bargain, which was bold enough to challenge the old raw stuffs in their own field. Among those on whose judgement the question depended, cast steel, which had hitherto only found application for objects used in the peaceful pursuits of life, was, to start with, perfectly unknown. Certain advantages of the new metal for gun tubes had soon to be acknowledged, such as its resistance to wear in firing, and its great strength, but such advantages did not decide the matter, besides with the old smooth-bored muzzle loader, the superior strength of cast steel could not come into play, and the rifled breech-loading gun, which was eventually fully to display the excellent qualities of cast steel, was still at the first stage of its development. Of course, many adverse incidents also occurred, until at length the design of the gun tube and the breech-closing mechanism, the nature of the powder and the design of the projectile had been so adapted to crucible steel, and had been so perfected, that artillery was raised to the high ballistic power which it could attain only through the particular properties inherent in cast steel. This was the state of affairs, when Alfred Krupp after the first big orders in the beginning of the 'sixties, definitely decided to take up the manufacture of ordnance. The problem was quite clear to him. Fully believing in the final triumph of cast steel, he was absolutely convinced that, in the future development of artillery, the rifled cast-steel gun would prevail. If he wished to see this goal reached in a short time, he must not restrict himself to the manufacture of good cast steel, and leave all other things to take their course, on the contrary, he must take it into his own hands to bring out the higher ballistic power of the cast-steel gun; he must make himself independent, in order to develop his own system of artillery; he must take up designing also, and himself try to find the quickest and surest way of progress. His former experience too, reaped on other fields of manufacture, where the struggle had likewise been to make cast steel prevail over the metals hitherto used, but inferior in quality, especially that connected with the introduction of cast-steel railway material, guided him in forming his resolution. It was a resolve, no doubt, fraught with heavy responsibilities; he ventured out into a domain where the works had not yet gathered any experience, besides, the idea that private works should design guns for themselves was so new in Germany—as was later on the idea that a private entrepreneur should establish for himself a big testing ground—, it meant establishing competition with the government institutions, and the state gun factories, which hitherto had been wont to look upon this as their own prerogative. It was in the nature of things, besides, that new problems would present themselves, particularly in the construction of gun carriages and mounts, and the manufacture of ammunition, and that ever more and more the works' sphere of activity would expand. It was natural, that the whole importance and final consequences of this resolve were only gradually recognised, and that the development of the works to which it gave cause, proceeded step by step. However this may be, a man so far-sighted and experienced as Alfred Krupp, could not be mistaken as to the significance of the step he took.

The commencement of the designing of artillery forms perhaps the most important epoch in the history of the evolution of the Krupp works, and while making full allowance for the prudential reasons that were instrumental in Krupp's decision, it must still be admitted that Krupp's own personality in the chief place turned the scale. It was impossible for a man like him to decide otherwise, impossible that he should restrict himself to the production of steel blocks for guns, when in doing so, he would have excluded himself from exercising any influence on the raising of guns to higher ballistic power. This would have been altogether against his nature, which was most strongly attracted by any new and important problem. It is one more manifestation of his extremely self-reliant nature, which was impelled to work out any matter he undertook, by his own strenuous and incessant labour and perseverance, from small commencements to its highest development and perfection. His enthusiasm refused to admit serious apprehensions, he foresaw the future possibilities, and firmly believed in the cause undertaken; besides, the path on which he now set out, perfectly coincided with his personal bent and talents. Alfred Krupp was endowed with an unusual talent for design, instances of which were given in the completion of the machinery and working appliances of the Cast Steel Works, and which now was to find a new and wider field of activity. From the first years, after the construction of artillery had been undertaken, a number of drawings by his own hand have come down, which contain some remarkable ideas. Very frequently his ideas were far in advance of his time. There is for instance an interesting sheet of the year 1855, representing a field-gun carriage with an elastic device to counteract the recoil shock. Four years afterwards, he added a folding spade to the trail of the carriage, also a drag rope, passed through the wheels and hooked by its ends to the trail, a gunner's seat, and traversing gear for the accurate laying of the gun. The object of this was to obtain greater rapidity of fire. It took many years before these appliances to field-gun carriages came into use.

The new work was so energetically pushed ahead, that in 1862 several cast-steel breech loading guns, designed by Krupp, could be exhibited in London. Five gun tubes, of calibers between 9·52 and 22·86 centimeters, of which the heaviest weighed 9000 kilogrammes, were shown there. The latter created a well deserved sensation by its size, the purity of the cast steel, and the excellence of the workmanship, for in those days no one but Krupp was able to produce a cast-steel block of the size required for such a gun, of such perfect homogeneity; to display the latter property thoroughly the bore of the gun had not been rifled, but brightly polished. In order to demonstrate that the works were now equipped for the complete finishing of rifled guns, a set of seven portions of gun tubes, with different patterns of rifling were exhibited, of which, by the way, mention has been made above. The result of this exhibition was a number of orders from several English works for inner tubes of big guns. To Armstrong alone during the following years, several hundreds of inner tubes for big caliber muzzle-loading guns were supplied. Orders from other quarters became more frequent, and now an ever-growing number of states asked for Krupp cast-steel guns. With such successes, however, untoward incidents could not fail to come during the wearisome efforts to work out the designs best suited to cast steel; such misfortunes, for instance, as the bursting of a 72-pounder, the breech-end of which was not correctly designed, and the rupture of the breech ends of several Krupp steel 4-pounders during the war of 1866. These accidents, it is true, could not be attributed to any fault of the material; as was eventually proved, they were due to certain imperfections of design, in particular of the breech-closing mechanism which, however, Krupp had not designed, nor the tube. Be this as it may, such incidents created many adversaries to cast steel, and so the fight between it and its older rivals, iron and bronze, was waged for some time longer. Only after the war of 1870/71, could the ballistic capacity of the cast-steel gun be raised so much, that even the best bronze had to yield to its supremacy. When, in the beginning of the 'nineties, high explosive shells were introduced, and it consequently became necessary to make the guns of strength to resist the effects of a shell bursting in the bore, it was Krupp's nickel steel only, that could fully come up to this requirement.

In taking up the construction of ordnance, Krupp, in opposition to the system of rifled muzzle loaders adopted in France, declared himself in favour of the breech-loading system as adopted in Prussia, with gas-tight forcing of the projectile. The great question now was, what kind of breech-loading mechanism should be selected. Instead of those then in use in Prussia, namely the Wahrendorff plug, and the double wedge, Krupp from the beginning decided in favour of the single wedge, which even to this day forms the basis of all wedge mechanism designed by the works, and which in a long series of different phases of development, have all sprung from that first single wedge mechanism. It was a flat wedge fitted with different kinds of mechanical devices for its manipulation, fixed to the back face of the wedge. The breech end of the tube was slit in two, in a horizontal direction, for which reason tubes of this design were called lip tubes. A tube of this kind of 9 centimeter caliber with different kinds of breech mechanism was sent by Krupp to London in 1860, when he was applying for an English patent. It was there exhibited in the Royal United Service Institution at Whitehall, until the year 1903, when it was returned to the Krupp works, and added to their collection in the Museum. It was the first breech-loading gun of Krupp's own design. A similar gun with breech mechanism, of the year 1861, is now kept in the Arsenal at Berlin. The splitting of the breech end entailed a weakening of the gun, and therefore was given up in 1861, so that from that time forward only solid breech pieces were made, with a hole to lodge the wedge set square to the axis of the bore. Here begins that series of breech mechanisms, which from the wedge lever and locking screw with slide, goes on to the screw thread removed on one side in order to move and lock the wedge, and eventually leads to the modern breech mechanism. As early as the end of the 'fifties, Alfred Krupp was already engaged in seeking a safe gas-check, to be applied to the breech face of the bore, the importance of which he at once saw. A sketch, drawn by his own hand in 1859, shows different kinds of ring and pad gas-checks, of steel, copper or paste-board, which were to be inserted loose, either in the bore or in the wedge. Krupp was granted an English patent in 1862 for such obturators of ┏ section and of ◤ section. He was, however, not able to get a patent in Prussia, either for his gun tubes or for his breech mechanism. It must not be left unmentioned, that the gun carriage of the gun alluded to above of the year 1861, now in the Berlin Arsenal, was fitted with a traversing gear for the accurate fine adjustment of the gun. Krupp had sent this gun to Berlin to be tried in support of his demand for the Prussian patent. The result of the trial, which was communicated to him in 1863, was worded thus:—"In firing, no serious defect has shown itself, but the necessity of a device of such complicated nature, delicacy, and costliness, and the increase of weight in the carriage, which it occasions, could not be acknowledged; these considerations have caused all further trials to be suspended."

The year 1865 marks another important epoch in gun-tube design, namely the manufacture of compound or built-up guns. In that year Russian inspecting officers gave Krupp the first suggestion, to try the hooping of the 21-cm guns for Russia, in order to make them stronger, as massive cast-steel guns had arrived at the highest limit of their power. In the meantime circumstances had occurred which urgently demanded an increase of the capacities of artillery. After the experiences of the Crimean war with floating batteries, France had built, in 1858, the first armoured frigate, and had thus forced England and the other naval states to follow her example. Since then the armour of ships had so increased in strength and power of resistance, that it became a necessity to build guns strong enough to fight them. The Russian suggestion therefore was of extreme importance to Krupp, since it showed him a way which might lead to the development of higher ballistic powers in guns. Technically this innovation is founded on the following considerations:—in a massive gun tube the bore is drilled out of the forged cast-steel block. The various layers of the metal encompassing the bore of such guns, are less affected by, and resist the gas pressure produced by the powder charge in proportion as their distance from the bore increases. It is therefore of no use to go beyond a certain thickness ot metal round about the bore. An increase of the total strength of the gun tube could be obtained only if the various layers, regardless of their distance from the face of the bore, could all be made to take an equal share in the resistance to the gas pressure. These conditions were obtained in the so called built-up gun in this way; on an inner tube, of comparatively thin metal, hoops slightly heated were shrunk, these hoops having, when cold, an inside diameter slightly less than the outside diameter of the inner tube.

The increased strength of the gun, obtained by the built-up system, at once placed the question of a corresponding breech-closing mechanism in the foreground, for with the ordinary wedge mechanism the increased power of such guns could not be utilised to its full extent. In firing trials it had been noticed, that the higher strain to which guns were exposed in the efforts to obtain greater ballistic power, easily had the effect of tearing off the breech pieces, the fracture beginning in the sharp re-entrant angles of the wedgehole or slot. An attempt to remedy this inconvenience was made by rounding off the back face of the wedge slot. This gave rise to the cylindro-prismatic breech wedge, first employed for small calibers, and then for the 4-pounder field gun ordered by Russia in 1864. In Prussia this breech-wedge was adopted together with the new gun C/73 after the war of 1870/71. As the cylindro-prismatic breech wedge, the Broadwell obturator was introduced in 1867,—an obturator ring having its seat not in the breech wedge but in the bore. The construction of a cylindro-prismatic wedge for small calibers showed the way to the solution of the breech wedge question for big calibers, whereby it became possible to apply the building-up principle to heavy guns also. The cylindro-prismatic wedge for big calibers C/1866, was fitted with a transporting screw on account of its big weight, so as to obtain an easier manipulation in opening and closing the breech. One drawback to this wedge, the complicated locking device against spontaneous opening of the breech during fire, was avoided in the improved construction C/68. By this a breech mechanism was found, which owing to its practicability remained in use, until quick-firing breech mechanism was introduced in the course of the 'nineties. Although the hooping of guns had already been practised in France and England, Krupp nevertheless was the first to apply the system to cast steel and to develope and perfect it. Many and various trials had to be made before perfection was reached, as the works lacked all experience, there were for instance questions to be solved, as to the most convenient kind of heating, the temperature to which the hoops were to be heated, and the difference of diameters for the shrinkage. The first experiments were made in spring 1865, on a 9-cm gun, which is still preserved in the works' collection. Other trials followed with 21-cm guns, which from massive guns were transformed into built-up ones. On the basis of the experience thus gained, the design of built-up guns with raised ballistic power was worked out. For this task Alfred Krupp needed an assistant, practised in artillery matters, and well versed in all questions connected with it, and consequently able to utilise the results of theoretical research, and to work out the improvement of the ballistic power of guns on a scientific bases. Engineering in those days did not occupy itself with such questions, therefore the leading engineers at the Krupp works were not versed in them. Krupp found the assistant required in W. Gross, who at that time was commissioned as artificer to the Artillery Experimental Committee at Berlin. Gross entered the service of the Krupp works on July 1st 1864, and from that time became the originator of all intellectual progress in the manufacture of gun tubes at the Krupp Cast Steel Works.

The improvements effected in the construction of gun tubes alone were not sufficient to obtain a striking energy great enough to perforate the armoured targets representing the armoured protection of the latest battle ships. The results obtained in North America and Russia with coarse-grained and prismatic powder, induced Krupp, in 1865, to undertake experiments with a prismatic powder that he had made in a hand-worked powder mill of his own design. The result was so satisfactory that a mechanically-driven powder mill was ordered from Professor Wischnigradski at St. Petersburg. This press arrived at Essen in 1866, and was handed on to Ritter's powder works at Hamm on the Sieg. In the meantime, the works had produced one 24-cm hooped gun for Russia, and one for themselves. A series of experiments, beginning in June 1867, were now started on the Essen proving ground, with prismatic powder of different densities and with seven perforations. The gas pressure was measured by the Rodman apparatus, and the velocity of the projectile by the electro-ballistic pendulum of Navez-Leurs, and later on by the Le Boulengé chronograph, which worked more exactly. This apparatus had only just come out, and the inventor himself brought it to Essen, and explained its application. But as the proving ground at Essen was too limited in space, to afford a clear picture of the ballistic power of the guns, the experiments were continued at St. Petersburg by the Russian Artillery Committee. Before this 24-cm hooped gun was sent off to Russia, it was fitted, with the central vent passing through the breech mechanism, and following the axis of the bore, instead of the old radial vent passing from above, through the wall of the bore. This device not only avoided a weakening of the gun, but also secured a much more favourable combustion of the powder charge, as regards its ballistic output. The gun had also been provided with an eccentric powder chamber, the axis of which lay higher than that of the bore; this was intended to improve the accuracy of fire, and to diminish the erosion, it had already been tried in several guns with good success. By exchanging information as to the results gained by the Krupp works and the St. Petersburg Experimental Committee, with the same 24-cm gun, opinions on the ways and means to be applied, in order to obtain a higher efficiency, were much elucidated, and the experience gained in these experiments afforded a basis for the further development of hooped guns. In consequence of these favourable results, the Russian Government, about the middle of the year 1868, ordered a large number of 24-cm hooped guns, and decided that a 28-cm gun, which had been ordered before, but of a different design, should be the same as the 24-cm gun. It was the first gun made by Krupp on the new system of such big caliber. Trials of this gun also, which were made about the end of August 1868, proved so satisfactory, that in the following year Russia ordered 76 of them.

In Prussia also experiments were now begun with Krupp hooped guns. After the war of 1866, a fleet of ironclads was projected for the North German Federation, and the question arose as to the proper type of gun for these ships. The first trials made by the Ministry of War, to whose department the Navy then belonged, with 21-cm massive guns had not given satisfaction. In January 1867, two 24-cm guns were ordered from Krupp with a double layer of hoops shrunk on. They were delivered about the end of 1867, and were the first guns of the hoop system, as developed by Krupp, which Prussia bought. In England at that time the 9-inch (24-cm) muzzle-loading Armstrong gun (Woolwich system) was in use, and this gun possesed the ballistic power which the German Navy required. As it was an urgent matter to decide the armament of the ironclads which had been bought abroad for the North German Navy, the Ministry of War ordered a 9-inch Armstrong gun to be compared with the Krupp 24-cm (96-pounder) hooped gun. In a preliminary trial on the proving ground at Tegel near Berlin, in March 1868, the Krupp gun did not answer expectations, and Krupp therefore suggested arranging one gun for central priming, and using prismatic powder instead of the ordinary fine-grained gun powder, declaring at the same time his willingness to place 20 hundredweights of prismatic powder from his stock at the disposal of the committee. Krupp's propositions were in this instance rejected. When in the comparative tests on the 2nd of June 1868 the Woolwich gun proved superior to the Krupp gun, the decision to adopt Armstrong muzzle-loader guns seemed inevitable. For the armament of the ironclad frigates 'König Wilhelm', 'Kronprinz' and 'Friedrich Karl', 41 guns in all were required, of 8, 9 and 10-inch calibers. It was alleged in favour of the Armstrong gun, that these guns with their mountings, accessories and ammunition had gone through practical exercise under all conditions on board, and that in respect of design they were finished and tried. Krupp objected, pointing out the higher efficiency of his guns when prismatic powder was used, and he obtained a postponement of the decision, and a promise that new trials should take place. A written answer from the Ministry of War, of the 21st of June 1868, says on this subject:—"I have the honour to inform you, that His Majesty the King has deigned to decree, in consequence of the petition presented to him personally by your agent Mr. Meyer of this place, on the 10th of this month, and of my report regarding this matter, that the decision of the question, whether the ironclads are to be armed with Woolwich or with breech-loading guns, shall be postponed, until the trials already begun with the cast-steel 96-pounder with central priming through the wedge and prismatic powder shall have proved that the efficiency of the 96-pounder is at least equal to the Woolwich gun of the same caliber, which may be assumed to be the case from information received from Russia on the results obtained there with 9-inch breech-loading guns. The General Department of War will issue further orders for hastening the termination of these trials."

In these competitive trials, which came off on the 7th of July 1868, the Krupp gun arranged for central priming and using prismatic powder proved victorious. The Experimental Artillery Committee in their report drew the following conclusions from these results:—"The

24-cm breech-loading gun is, in no small degree, superior to the 9-inch Woolwich gun as regards accuracy of fire and penetrating power, even when only firing Gruson (chilled cast-iron) shells, if, however, it be equipped, for such fighting purposes as demand a specially great artillery effect, with Krupp's steel shell, its superiority is much augmented". This opinion was absolutely confirmed in a second trial with Krupp steel shells, which took place on the 4th of August 1868. These shells were of an hitherto unknown design. The works had in 1867, when firing against armoured targets, observed that the thick lead coating which was then used as driving means, detached itself at the moment of impact of the projectile on the armour. It was correctly deducted, that the dimunition of weight caused by this, also reduced the perforating power of the projectile. Again, the ribs of the body of the projectile laid bare in this way, prevented the projectile from penetrating into the armour, when it had struck even in an only slightly oblique position. Following out these observations, Krupp now manufactured steel shells of a smooth cylindrical surface on which he had a thin lead coating soldered. The penetrating effect of these shells was considerably higher, and with such shells too, the second trial firing was carried out with success. An eye witness of the firing trial at Tegel on the 4th of August 1868, writes in reference to it:—"The effect of the steel shell actually surpassed all expectations, however high they had soared. The rejoicing among professional men was beyond description; I have never seen such joy, such exultation. It was as though the one round, that almost destroyed the target, had freed them from a nightmare, the Woolwich nightmare." In consequence of these two firing trials, Krupp's breech-loading gun was adopted for the armament of the new ironclads. Thus the German Navy was saved from the adoption of the English muzzle loader, and at the same time from a retrogade step, which would have been followed up by great disappointment and useless sacrifice of money, whereas the British Navy had to make several further changes in their gun system.

The adoption of the Krupp breech-loading gun for the German Navy forced the Cast Steel Works to consider the building of mountings for naval and coast-defence guns; these latter were also taken up, because naval guns, in a general way, would also serve coast defence purposes. Krupp had to take up this new branch of manufacture, because the evolution of gun-tube design by firing trials, could hardly be separated in practise from advancement in the design of carriages and mountings, and it consequently was convenient, both for purchaser and manufacturer, that the making of the gun and its mounting should be in one and the same hand. It was decided about the middle of 1868, to take up the building of gun carriages and mountings, a branch which afterwards developed into one of the most important departments of the Cast Steel Works. There were no small difficulties to overcome at first, for the works had to deal with an absolutely new branch, for which no experience in former manufacture could be utilised. It is true, that the English naval gun mounts could in a way serve as models, but they were exclusively intended for muzzle loaders, while Krupp had to adapt them to the breech-loading system. This necessarily entailed many modifications. Thanks are due to the considerate conduct of the Naval Authorities and the helpful advice they gave, in conquering, one after another, all the difficulties that stood in the way. As the works grew in experience, they became more self-reliant in the invention of design, as instances of which the following may be mentioned:—the elevating gear with toothed arc, the arrangement for automatic running out of the mount, which afterwards developed into the automatically running out upper carriage, also the hydraulic recoil buffer, and the central-pivot mounting. In the autumn of 1868, the designing and building of coast-defence gun mountings was taken up, which in general outline is similar to the broadside-gun mountings on board. They were front-pivot mountings, with high sides to the chassis, their traversing gear consisted of a chain wheel and a Cunningham gear, and were fitted with an hydraulic recoil buffer at an early stage. When the war of 1870/71 broke out, the coast-defence gun carriages had been so far developed, that the works could turn out useful carriages, but they were greatly in arrears with their producing power. Krupp was compelled to get the material he required for the mountings, such as sheet girders and angle irons, from other iron works, because his own were not yet equipped for the production of those things. These iron works, however, failed often in promptness of delivery, and as there was no great selection of works to which he could apply, Krupp very often got into great difficulties. After the war, he took the very first opportunity of making his works independent of others, by taking up the production of all building material necessary in the construction of carriages and mountings for naval and coast-defence guns. At the beginning of the war, these troubles were all the more felt, because the coast defence at the points most menaced by the French fleet, that is at the mouths of the Elbe, the Ems and the Weser, had to be completed with the greatest speed. Krupp gave his assistance in the best way he could, he pushed his works to the maximum of their productive power, regardless of expense, and without any definite order, had guns made on stock. Much was hurriedly finished, so that it could be used in an emergency, and much he placed at the disposal of the authorities free of charge. He wrote to his representatives, the "Procura":—"If we show such activity, as is demanded of, and performed by our countrymen in the field, if we multiply our exertions to the utmost, and if all departments work unceasingly, we shall be able to produce the Incredible, the Impossible. We will therefore not wait for any orders, we will proceed with our manufacture at once." With redoubled zeal, now that the country was in danger, he used every opportunity of strengthening the defence of Germany both by land and sea. In connection with this, an invention may be recalled, referring to a question which now once again claims our interest:—that of the gun to fight balloons. Krupp's balloon gun, indeed, did not come into use during the war, for the simple reason, that its very existence prevented any more balloons being despatched from Paris.

The Prussian coast artillery had no occasion for action in this war, and of the young fleet of the North German Federation only the small gunboat 'Meteor' had a chance of successfully turning her Krupp guns against the French despatch boat 'Bouvet' off Havana, while the German armoured fleet had no opportunity of testing the efficacy of their Krupp cast-steel guns. The artillery of the German army on the other hand had all the more chance of doing so, for their batteries had mostly gone into the field with guns made of Krupp's cast steel. Just as the needle gun had done in 1866, so the cast-steel gun now returned home from the war covered with glory. In the triumphal progress of the German army, it had played a most important part, and no meaner man than the Emperor Napoleon himself, that authority on artillery, said, that the German field artillery had been the decisive weapon of the war. By the way it had fought, the artillery had won the absolute confidence of all other branches of the service, and whereas it had formerly been classified with the "technical" troops, it now was placed on an equal rank, as the third arm of the field army, alongside of the infantry and the cavalry. Artillery had also become the most popular weapon, and as after the war of 1866, the name of Dreyse, so now, by the brilliant success of his weapon, the name of Krupp, the "Gun King", rose to enormous popularity. And if public opinion then overlooked the fact that it had not been Krupp who had fitted and equipped the guns, still it was right in so far, as cast steel, of which the guns had been made, was an essential factor in the absolute reliability of the guns, and consequently also in their success. It is true, that this gun, which helped our troops to conquer in France, had already fought on the battle fields of Bohemia, side by side with the needle gun, just as it did in 1870/71, and yet the success of the Prussian artillery had in no way come up to expectations then. This fact is a proof that not the mere condition and qualities of the arm itself, but only the manner in which it is used, is the guarantee for its success. A superior weapon will be conducive to victory, only if it be manipulated so as to produce its highest power under competent leadership. The spirit of progress in industry therefore must never flag, it must always remain mindful of its responsibilities, must ever remember that it is called upon to improve the arms for the defence of the country; such was the lesson which these two wars gave to the Krupp works.

# FROM CRUCIBLE TO BESSEMER AND MARTIN STEEL.

Whilst the working and machining of cast steel was making such great headway, in the 'forties, in the production of steel the old-fashioned method, apart from a number of abortive experiments, had remained substantially unaltered. The cementing process, the principle of which was the gradual carburisation of best bar iron by careful heating in the cementing furnace, still formed the basis of crucible steel. This process, together with strict supervision and many years' training of the workmen, had secured the reputed good quality and uniformity of Krupp's steel, and Alfred Krupp even at that time considered crucible steel melted from cemented Osemund unrivalled. His adherence to this old process was so tenacious, that even in the year 1873 he recommended repurchasing several hundreds of railway axles, forged, 25 years ago, from cast steel of the former quality. He advised this in order to secure a small stock of the "good material", before it was to late, and to keep it on reserve for special purposes. However, from an economical standpoint, this expensive and slow cementing process had its drawbacks, and thus with the increase of production from 1849 onwards, the problem of a cheaper method of producing steel also became acute. The manufacture of axles, tyres and especially guns demanded an increase in the total output of steel on the one hand, and larger individual ingots than before on the other hand. A period of marked progress in both the above directions ensued about the year 1850.

At first the question arose, as to how to replace the cementing process through which iron is very slowly converted into steel, by a quicker and more economical method. The experiments to melt cast steel from a cheaper material, especially from pig iron or direct from ores, had never been entirely abandoned, but had been continued all along, and with varying success, by a great many experts. At the Lohe iron works near Kreuzthal, with which Alfred Krupp later on entered into closer relations in the steel-puddling question, the Royal Inspector of Iron works Stengel had, among others, continually been conducting experiments with a view to obtaining cast steel by melting down spiegel and wrought iron, in accordance with Chief Mining Councillor Karsten's suggestions. Useful results were obtained neither here nor elsewhere. Also at the Krupp works a considerable amount of esperimenting had been done with various charges, ever since 1848, principally with charcoal hearth steel, at times with spiegel and Swedish iron, the cementing process, however, being all through retained as a basis. A decided change was only brought about, when puddled steel began to be used for the charge, first by way of experiment in 1852, and within few years entirely took the place of the cementing process in the manufacture of cast steel. The puddling process *i. e.*, the fining of pig iron in a reverberatory furnace, while constantly stirring it with iron rakes, was an old English invention, and had extended within half a century over all iron producing countries. In Germany too a remarkably good puddled iron was produced, and worked up mostly into products liable to heavy strains, such as parts of machinery, axles, wheels, rails, &c. The endeavours to bring out a good steel by the same process, had likewise been taken up in England, however, they did not prove successful. It was not until the 'forties that German works succeeded in solving this problem. For steel puddling, the fining process, which consists in the decarburisation of pig iron by the furnace gases and by the puddling furnace slag rich in oxygen, must not be conducted to the finish, but must be checked in time *i. e.*, when there is still a high percentage of carbon remaining. For this work skill and experience, together with suitable raw material, are the essential conditions to success. The so-called "steel pig", a pig iron with a very low percentage of phosphorus and sulphur, proved, after numerous experiments, best for the production of a good uniform puddled steel. These suppositions to a large extent were fulfilled by the small works on the Ruhr and in the Siegerland districts, and thus puddled steel first found its way from them into industry. German triumphs in the manufacture of puddled steel created intense exitement at the International Exhibition held in London in the year 1851, and provoked keen emulation; foreign, as well as German works, who were hitherto not acquainted with the puddling process, have introduced it since then. The Loherhütte in Siegerland, at that time the property of the State of Prussia, where since the beginning of the 'fifties puddled steel was procuded, also ranked among the afore mentioned works. Two puddling furnaces were erected, in place of the old plant, for charcoal hearth steel, and after 1853 the Lohe Works supplied their entire output in puddled steel to the Cast Steel Works.—Already previous to this, Krupp, assisted by Ascherfeld, had started on experiments in connection with the use of puddled steel in lieu of cemented steel as a crucible charge, with promising results. At first steel of various qualities was taken from sundry small works. The first material of uniform quality was supplied in the spring of 1852 by Gustav Zapp who owned old refined-steel works in Ründeroth. Zapp, even at an early date, had successfully introduced steel puddling, and ranked among the first producers of puddled steel for the welding on of the steel head on rails. The excellent quality of the afore mentioned produce induced Krupp to go to Ründeroth himself, accompagnied by Ascherfeld with a view to becoming acquainted with the steel-puddling process by personal observation. As soon as he had finally convinced himself of the superiority of the new method, he firmly resolved to set up in this line on his own account. The year 1855 saw the starting of his own puddling plant with four furnaces, for which the services of puddlers from Ründeroth were requisitioned, together with the newforge in the Mülheimerstrasse. The necessary iron was then mainly procured from the Royal Sayn works, which smelted a steel pig of exceptional purity in its Oberhammer charcoal blast furnaces. The working of the new plant, of course, did not at first answer expectations; defects in furnace construction, lack of experience, and finally also certain friction existing between the puddling and the melting works, where the new product was regarded with dubiety, arrested the success for about a twelve-month. After 1856, however, the puddling works—increased to six furnaces now—remained regularly at work, although the product was for some years not a uniform one. In the course of time only did the good quality and uniformity of the steel increase, especially after Krupp had made a point of seeing that the pieces of the bars, which had been broken up into short lengths,—precisely as with Osemund previously—were sorted, and then selected as a charge according to the particular purpose the cast steel was to serve. In this manner the manufacture of crucible steel was soon established again on as firm a footing, as when cemented steel was exclusively used. The balance between the heads of the melting and puddling works who watched one anothers movements with jealousy, was gradually restored to the benefit of all concerned, and to the satisfaction of Krupp. After having concluded the first experiments, Alfred Krupp had placed the puddling works under the management of his wife's cousin, Richard Eichhoff, who joined the firm in 1854, whilst Ascherfeld as before, remained manager of the foundry, assisted, from 1857 onwards, by the young Carl Uhlenhaut, who had been trained up as an analytical chemist at the Polytechnical School at Krupp's expense. Richard Eichhoff was a person of pronounced features of character, unflaggingly energetic and indifatigably industrious. Although not technically educated, he was well versed in the requirements of his department, which he delighted in energetically, and at times doggedly protecting against foreign influences. Eichhoff, like Krupp himself, and Ascherfeld, all from the school of life and hard work, attached more importance to experience and practical experiments than he did to theory and scientific reasons, and even the young Uhlenhaut being imbued, at the outset, with this empiric way of thinking, it is not astonishing that the purely and scientific preception of metallurgical processes, which was at that time in its infancy, was not allowed much influence in the Cast Steel Works in the 'fifties. It was not until 1860, subsequent to the Bessemer, and later on to the Martin process, that a change took place in this respect, and it was then Krupp who was ever ready to comply with justified requirements of science. — Krupp's puddling works, however, continued to thrive admirably, although they rested on entirely empirical methods, and increased considerably together with its auxiliaries. The reliability and experience of Krupp's puddlers gradually aquired a wide reputation, and finally puddled steel was not only produced in large quantities for his own requirements, but also for purposes of sale. Up to the year 1863 the first puddling shops were increased to 17 furnaces, and in 1866 a second large puddling plant was erected in the southern quarter of the works which, besides supplying charges for crucible castings, was employed predominantly for the sale of puddled steel to outside consumers. For many years these puddling works of Krupp's ranked among the most interesting departments of the factory, and were a great source of attraction to every visitor. In the flat arched furnaces charges of pig iron weighing about 200 kilogrammes were emptied over a thick layer of hammer scale, which together with the products of the combustion of the silicon and manganese in the pig iron, forms a strongly oxidizing slag. The coal or gas flames which passed over the iron were reverberated by the roof of the furnace, and within half an hour melted the charge. By constant puddling with long iron rods, the metal bath was then brought into close contact with the oxygen given off by the slag, whereby the carbon gradually got consumed, whereas the iron became more and more refract and finally was reduced to a pasty mass, which the puddler, after having divided it up into several smaller lumps, once more worked through on the hearth for some time, and finally, the whole process having taken about two hours removed the balls one by one, which were immediately freed from their slag by squeezing and rapidly forging them under a light hammer, after that they were rolled out into long, thin bars. Whereas puddled steel for general purposes was soon superseded by the more recent inventions in the field of the ingot steel, it continued to play an important part as the chief component of the charge for crucible steel until modern times. Much later, and then only now and then, were experiments untertaken with a view to replacing the puddling process by more up-to-date methods, the outcome of which was that puddled steel as raw material for the crucible charge gradually began to be superseded by steel suitably prepared in the openhearth furnace. It was not until the year 1910, however, that the remaining puddling furnaces of the Cast Steel Works fell into desuetude.

The introduction of puddled steel was in strict consonance with the one requirement of the advanced times, the need of an economical and suitable charge for the increased production. The old plant, however, for handling such output was inadequate now. Even prior to introducing the puddling process, Krupp was more than once obliged, to proceed with the enlargement of his crucible-steel foundry, in view of the increasing orders in springs and axles. In addition to the afore mentioned new premises, erected in 1845, containing 14 double furnaces, two further sheds were added from 1849 to 1851, containing 20 furnaces each with a capacity for four crucibles. The manufacture of crucibles had also made corresponding progress. From 1851 Ascherfeld began systematically to train the workmen to cast from several crucibles heavier ingots for required locomotive axles and marine shafts, with the same safety as small ingots. In the April of that year a casting was made for the first time from 31 crucibles, which were emptied in five minutes, then step by step he went up to 40, 60 and 84, and soon Ascherfeld was able to report to Alfred Krupp, who was at that time staying in London, that everything had succeeded admirably, and that his men were extremely zealous in fulfilling more than their duty. The successful casting of the historic steel block weighing 4300 pounds, which formed the "chef-d'œuvre" of the German section of the London Exhibition, and secured for Krupp the highest award, the "Council Medal", terminated this first period of experiments. For casting the exhibition block the crucibles from all the melting shops had been brought together. From some of these first ingots of considerable size, among other things a pair of unusually heavy crucible-steel rolls were manufactured for the old plate-rolling mill at Spillenburg, to which Friedrich Krupp had supplied the first heavy cast-steel implements more than thirty years previous to this. Even at that time, as at the present day, large ingots were not cast by uniting the contents of all crucibles into one ladle, but by pouring direct from each crucible into the mould. In doing this, success mainly depended upon the reliability and skill of the workmen who were trained to the work of lifting out, carrying and pouring out the crucibles, at first empty and then filled with red hot ashes. Whenever Ascherfeld cast a large ingot, he assembled the men together from all departments and then gave his orders from a commanding position. To be insured of uniform heat at the right moment with all the crucibles and furnaces, all these were regulated by the slowest working furnace. He did not begin the casting until the contents of this furnace had attained the correct temperature. The workmen marched in two even files from the melting furnaces, where the founders handed over the crucibles to them, to the casting trough, which was later on replaced by long gutters, to allow of simultaneously pouring out several crucibles. Here two men at a time poured out their crucibles, and then passed on to take away the empty crucibles and to fetch fresh ones. A small recompense in the way of money and—otherwise strictly prohibited—whisky was distributed among the workmen at the finish.

The possibility of manufacturing cast-steel blocks weighing more than two tons was an important step forward; however, these ingots still were inadequate when once orders came in for heavy marine shafts. Already in 1854 Krupp found himself obliged to add a new foundry with 20 furnaces to his existing plant. Simultaneously, the oldest melting shop originating from his father, and which had been in activity for 35 years, was closed and fitted up as a steel-grinding shop. In the ensuing year the capacity of the entire foundry department was once again doubled. The last furnaces to hold four crucibles were erected on these new premises, later on only such with a larger capacity were constructed. The block weighing 5000 kilogrammes, exhibited at the Paris Exhibition in 1855, testified to the efficiency of the Cast Steel Works that had then been attained, where now 47 furnaces with about 370 crucibles were available. The premises were not extended again after this until the beginning of the 'sixties, when the economic crisis of 1857/59 had been overcome, and consisted in the rebuilding of the old furnaces, which were then arranged in two rows, each furnace holding now 12 crucibles. As from the very commencement, these furnaces also were situated under the floor of the casting shed, so that the lifting out of the red-hot crucibles was accompagnied with difficulty. Passingly an arrangement was provided for placing the crucibles upon a platform which could be lowered into the furnace and raised again by means of a lever. Owing to mechanical difficulties, however, this device was dropped and the old reliable method of letting down and lifting the crucibles by means of tongs was once again resorted to. Important improvements were obtained by arranging the furnaces to hold twelve crucibles each. In the conducting of the draught and the uniform heating of the crucibles great skill had been aquired; the heavy iron furnace covers which were hitherto suspended, lifted and lowered by chains from the beams of the roof, now ran on rollers for lateral displacement, and the total output of the foundry, withoutany extensions, could be increased manifold, owing to the greater capacity of each individual furnace, with the result that a crucible-steel ingot weighing 20,000 kilogrammes could be exhibited in London in 1862. The then rapidly increasing manufacture of ordnance, and the supply of large shafts for transatlantic steamers once again necessitated extensions being made, and these continued from 1863 until 1872, bringing the number of furnaces in the main melting department in the northern quarter up to 136, and the number of crucibles which could be simultaneously employed up to 1600 odd. By this it was possible to obtain castings weighing up to 52 tons, without difficulty; a steel ingot of that weight caused no little sensation at the International Exhibition in Vienna in 1873, and secured for Krupp as highest award the Diploma of Honour of the Exhibition. Meanwhile, after 1864, a second crucible foundry had been erected in the southern quarter, mainly for the manufacture of railway wheels by the steel casting process. Here now and then charges of Bessemer steel were employed, but soon a large puddling plant was added to the foundry in addition to large extensions. Puddled and crucible steel were produced here in large quantities for sale, and for further working up in the Cast Steel Works. The employment of gas fuel for hearth furnaces, which had begun in the second half of the 'sixties, having proved satisfactory, the crucible furnaces were also partly constructed for gas heating, and at the same time enlarged to take 18 crucibles. The above improvement was first made in the southern quarter of the works, where at that time a third large foundry with 30 furnaces had sprung up. Since 1872 the same system had also been introduced into the large foundry in the northern quarter. The utilization of these new arrangements was, it is true, delayed by the economical crisis, in fact after the disproportionately rapid development of the early 'seventies receded so considerably, that in 1874 the new foundries in the southern quarter with their modern gas furnaces covered the whole requirements, and the remaining foundries had to be closed down. In Alfred Krupp's time the foundries never surpassed the stage they had reached in the 'seventies, for apart from the economical depression that ensued, the new processes for the preparation of steel, which had in the meantime intervened—the Bessemer and the Martin processes—had had their share in superseding cast steel in its previous fields of application.

Before going into details of these new branches of the works, we must mention an event which was brought about by the enlargement of the cast steel production, and the introduction of the puddling process, and the results of which have influenced the entire development of the works, viz the purchase of the Sayn works in the neighbourhood of Neuwied with its blast furnaces and ore fields. The iron works at Sayn which was constructed in 1769 by the Archiepiscopal Government of Treves, and became the property of the Crown of Prussia in 1815, was connected with an important iron foundry and machine factory. For many years it produced a superior quality of puddled iron, and also supplied considerable quantities of cast iron for the Spandau Gun Factory, and above all castings for objects of art. In earlier times, Alfred Krupp himself had occasionally employed Sayn iron for objects of special purity, and had also ordered the cast-iron jacket from the same works for the first 3-pounder. Apart from the blast furnace there, which chiefly turned out foundry pig iron, there was also in Sayn a small charcoal blast furnace on the Oberhammer, and a third one also at Mülhofen; all three furnaces worked up spathic ore and brown hematite of a specially good quality, and chiefly by means of charcoal smelted from these ores, steel and ordinary pig and "spiegel" of exceptional purity. For some considerable time Krupp had been procuring the Sayn steel pig for his puddling works with good results and with his business in this line continually increasing in the 'sixties, accompanied by the ever-growing demand for pig iron for the iron foundry and the Bessemer plant, he had a desire to make himself independent in the production of pig iron, by acquiring the whole of the Sayn works with its blast furnaces and iron ore mines. The fear that other cast steel factories, which had since sprung into existence might possibly likewise proceed to secure Sayn iron, and by the aid of it might be able to successfully compete with Krupp's crucible steel, also played an important part in this resolution. The necessity of this transaction gradually attained such great importance in the eyes of Krupp that, unless he took this step, he saw the future of the whole Cast Steel Works at stake. The Prussian Fisc, for which the works had then but little worth, were just at that time entertaining the intention of disposing of them, and as early as 1864 a provisional agreement was concluded between the firm and the Ministry of Commerce, when the Bochumer Verein who were at that time keen competitors of Krupp, suddenly came forward as interested parties for the Sayn works, and challenged Krupp's acquisition of the works, endeavouring to secure them for themselves by offering a higher price. By this step Krupp saw the life interests of his works jeopardised to the extreme, and passed through a most anxious and troublous period, until the acquisition was at length ratified in March 1865 for half a million Talers. Later on Krupp wrote in his reminiscences of those months of suspense and apprehension:—"During the course of my business career and even in times of need, I have never experienced such distressing days." With regard to raw material for the puddling process, the Saynerhütte in the future fulfilled the hopes which Krupp had placed on them, and he himself rigourously watched that only the best, no matter at which cost, was supplied for the production of crucible steel. "For Sayn the chief item on the balance sheet is the honour" he once said, when discussing the possibility of reducing the cost of production. Besides steel pig for the puddling works, the Sayn works produced large quantities of foundry pig, on the other hand it scarcely played any part in the subsequent large pig iron requirements of the Cast Steel Works for the production of ingot steel. In spite of this, the acquisition of the Sayn works for the Cast Steel Works was an important step towards establishing their own independence. By this step the way of self-production of pig iron was opened, and owing to the peculiar nature of Krupp and of the works founded by him, it had to be followed up in such a manner, that the aim finally was fully achieved. However, the iron works at Sayn, and also the Oberhammer, participated no more in the ultimate enormous development which we shall refer to later on. They were small furnaces with a daily output of 5 to 9 tons, which originated from the time of charcoal burning, and which adhered to the old method of working, although in consequence of the difficulty of obtaining good charcoal they were partly fired with an addition of coke. Their annual output was accordingly also a very small one, and only after the purchase of further works which were more favourably situated, did the production of iron by Krupp's blast furnaces, at the commencement of the 'seventies, assume larger propositions. The antiquated furnaces at the Oberhammer works and in Sayn naturally became still further unimportant after that time, and in 1878 stopped working altogether. Thus smelting with charcoal finally ceased at the Krupp's works.

Krupp did not feel the necessity of larger supplies of pig iron until he took up the Bessemer process. Experiments to produce liquid steel other than in crucibles had first been conducted with success in the 'fifties. Uchatius steel which, like cast steel, was melted in crucibles but from pig iron and iron-oxide ores, caused quite a sensation, especially in Austria and France, and was the cause of Krupp becoming apprehensive of its detrimental effect on the cast-steel market there, but the employment of the invention did not prove lasting. On the other hand Bessemer's experiments to produce liquid steel from pig iron by an entirely new method gave rise to quite a revolution in the steel industry. In the older steel fining processes the pig iron melted on the hearth was made to trickle through the blast, which, besides the slag rich in iron oxide, had a refining effect on the iron accumulating on the hearth. Bessemer on the other hand forced the blast through the liquid iron contained in an iron pear-shaped converter, making the important discovery that in this process of decarburisation one attained such an increase of temperature that in spite of its higher melting temperature the refined steel remained liquid without further combustibles having to be applied. It was thought at the time that this rise in temperature was mainly due to the combustion of iron and carbon, now-a-days we know, that it is brought about principally by the oxidation of silicon and manganese. Without employing more fuel than was necessary for the preliminary melting of the pig iron, Bessemer by eluding the old fining process and the melting in crucibles obtained steel direct, ready for casting.

Alfred Krupp received in 1855 the first news of Bessemer's success through his English representative Longsdon, and did not hesitate to at once secure the application of the process in Germany. He was not acquainted with the properties of the new steel, but if it should prove equivalent to crucible steel, he would be compelled to fear that the life interests of his factory would be endangered by this new and considerably cheaper process. In this situation he acted quickly and resolutely. As early as April 1856 he applied, with Bessemer's permission, for a patent for himself in Prussia for Bessemer's invention, but met with a refusal. As, however, it was many years before Bessemer really saw the principle of his process, above all the application of a pig iron which should be as free from phosphorous and sulphur as possible, Krupp did not suffer any harm through this refusal. In the meantime he had been attentively watching Bessemer's experiments, and started fresh negociations with him, which were begun in 1859, and in the following year sent Uhlenhaut and Eichhoff to England to study the process. After their return he immediately proceeded, to carry it into operation. The first Bessemer works in Germany thus were started in 1861 and were conducted for many years with the strictest secrecy, and to the misguidance of inquisitive parties under the name of a wheel rolling mill. They were erected on the premises of the Cast Steel Works to the south of the hammer "Fritz". These works, although but a small beginning of the future enormous development of the production of ingot steel, were nevertheless for that time very important. At first two wrought-iron converters for a charge of 2000 kilogrammes pig iron were ordered in Sheffield, the first being set to work at about Easter 1862. Without awaiting the arrival of the second, Krupp at once resolved to erect two larger converters each for charges of 5 tons, both likewise ordered in England, but not delivered until the ensuing year. In the meantime the Bessemer works, under Eichhoff's management, were started, and from the very first year experiments were made in practically all branches of production of the Cast Steel Works, to employ Bessemer steel in lieu of the expensive crucible steel. Alfred Krupp displayed a lively interest in the further development of this branch of the works, and his foresight was shown by the fact that he soon recommended the employment of cupola furnaces, in compliance with an English proposal, for melting pig iron, in place of the reverberatory furnaces which were at first built, and had them constructed by way of experiment. Eichhoff opposed every change made in the process, and the result was at that time indeed by no means a favourable one owing to unsuitable coke. The reverberatory furnaces, at first heated by coal and afterwards by gas, were therefore retained until 1875. In principle however Krupp's idea was correct, and was accompanied by the best results when subsequently carried out. The Bessemer works continued to increase rapidly. In 1863 the first English 5-ton converters were set to work which owing to their being erected in a slanting position in the corners of the plant the workmen called "the crooked", whilst the older smaller converters were called "rats". Then already the Bessemer plant was producing twice as much steel as the crucible foundry. The hope of being able to replace cast steel qualitatively by Bessemer steel was indeed not realised. The new product could neither challenge comparison with the crucible steel for guns nor for tyres or axles; thereupon Krupp abandoned the use of Bessemer steel for products subjected to heavy strains, and in 1863 cancelled the agreement made with Bessemer giving him the sole right of applying the process in Prussia. By so doing it became possible for further Bessemer steel works to be founded on Prussian territory. Krupp had become firmly convinced from his experience, that these factories which were now opening up in large numbers, could not offer much competition to him in his main products, and that he kept the lead, guaranteed to him by his long years of experience, in the production of large crucible-steel ingots. On the other hand, however, he clearly foresaw the great importance of the Bessemer process which rendered the application of steel on many fields possible, and being firmly resolved to take the lead in this direction also, he immediately suggested the enlargement of the works by installing four more converters of 5 tons each; the latter were manufactured from cast iron in the firm's iron foundry. It was then necessary to considerably extend the auxiliary departments of the Bessemer works, and the ground first chosen soon proved to be to narrow. This was the first instance that a boiler house, which under the conditions prevailing then was an enormous one, had to be erected away from the working plant, on the other side of the Mülheimerstrasse, and the steam piping had to be laid underground across the road. Krupp's expectation in the meantime having proved right, that the prospects at first doubtful for Bessemer steel being introduced in the manufacture of wheels and rails, would take a favourable turn, in 1865 steps were once more taken to extend the premises by erecting a second Bessemer plant with five large converters. Krupp's intentions even looked much further ahead. In order to make himself independent in his supply of pig iron which in the home market could only be obtained with difficulty in a composition suitable for the Bessemer process, he projected a large blast-furnace plant near Essen in close proximity to his Bessemer works. Alfred Krupp intended to have the Bessemer process carried out in a similar manner to that by which now-a-days the Thomas converters directly treat liquid pig iron from the blast furnace. The blast furnaces were to work different charges partly for rails and partly for tyres, &c., and their output was to go direct to the Bessemer works. The employment of blast-furnace gases for producing steam for the works was also provided for. This comprehensive project fell through, partly owing to an opposition of an interior nature, as Krupp's fellow workers objected to his large plans from justified precaution, and partly owing to the high charges for the transport of ores which such plant at Essen would have necessitated. On the other hand the enormous acquisition of the firm's own iron-ore mines and iron works which began towards the middle of the 'sixties, and which reached a climax in 1872, attended the development of the Bessemer works. The purchase of the Sayn works referred to previously had been principally made with a view to enabling the firm to produce the best steel pig itself for the crucible process. On the other hand Sayn iron was scarcely of any importance for the Bessemer process owing to its content of phosphorous. In spite of many experiments no success was achieved in obtaining for the Bessemer works a pig iron sufficient free from phosphorous, from the mines of the Sayn works nor from the iron-ore mines in the Lahn district, which were purchased at the same time. Only from the Horhausen ores, the best at the disposal of the Sayn works, was it possible to produce a pig iron equivalent to the English hematite, but these were the very ores which also formed the basis for the production of steel iron and for the puddling works and had to be reserved for them. Krupp himself declared that "like a miser he grudged every hundredweight of this ore which was employed otherwise than for the manufacture of cast steel". In point of fact only 6 per cent of the pig iron worked up in the Bessemer works was supplied by the Sayn works, from 1866 to 1870. At first English and Swedish iron, and also the superior pig iron from the Georgs-Marien-Hütte near Osnabrück were mainly purchased as raw material for the Bessemer works. Difficulties were, however, at times encountered in covering the rapidly increasing requirements. Only a manganiferous pig iron rich in silicon, but with the lowest possible percentage of phosphorous and sulphur could be employed for the method of working of that time, and the choice of such qualities in Germany was very limited. The purchase of important mines in the Sieg and Lahn district, and in the Westerwald could therefore but slightly interfere with the former dependence in the matter of procuring pig from other sources. It was not until 1872 that Krupp succeeded in establishing his independence in this respect. In conjunction with one Spanish and two English undertakings the "Orconera Iron-Ore-Company" was founded, which firm then acquired a territory of iron-ore fields in the north of Spain, that probably had no equal in the world, for richness and good quality of ore. Besides the Sayn works, Krupp now owned the Hermannshütte near Neuwied, acquired 1871, and the Johanneshütte near Duisburg, purchased in the following year, mainly in consideration of the production of pig iron for the Bessemer plant. The Cast Steel Works therefore commanded three blast-furnace plants of a considerable output for that time; their being situated immediately on the Rhine, benefited the working up both of home and Spanish ores. The ores were brought by the firm's own steamers from Spain to Rotterdam, thence by river craft up the Rhine right to the works.

Alfred Krupp had ventured upon these vast undertakings which in the first place were intended to secure the independence of the Bessemer plants, being firmly convinced of the great future for ingot steel. Some of the hopes with which he had taken up the Bessemer process, had indeed proved unrealizable, and the use of crucible steel had to be exclusively adhered to for many products. However, for other purposes, especially for springs and railway axles, as material for the casting of disc wheels, &c. the Bessemer process had by degrees gained a considerable field of application, the more so, as the same products were exclusively made of puddled or mild steel by other works which did not produce crucible steel, and were placed on the market at considerably cheaper prices. Krupp laid down the principle for the use of ingot steel that the products made from it should have to satisfy all requirements with full security. For testing the steel, the same tensile strength tests as those which had already been carried out for a considerable time with crucible steel, were introduced immediately after taking up the Bessemer process. Test bars from every charge were bent and broken, and the hardness and tensile strength estimated according to the angle of bending and the appearance of the fracture. From 1862 onwards regular tensile strength, upsetting and torsion tests were made with a newly invented English testing machine, and gradually chemical analyses were instituted as well. Thus were founded within the Bessemer works the beginning of to-days specification-tests station, where this English machine is still in use.

Rails became the most important product made from Bessemer steel. The oldest rails had been manufactured in England from cast iron in the form of grooved rails, and the first experiments were also carried out there with wrought-iron rails, at the beginning of the 18th century. England also supplied the rails for the first German railways until about 1840, when the manufacture of rails chiefly from puddled iron also developed in German works. The revision of the import duties in 1844 improved the situation of the German industry in relation to England's industry to such an extent, that the production of rails could be more energetically pursued, and with the introduction of puddled steel or iron rails with heads of puddled steel welded on, German industry acquired even a certain superiority in the 'fifties. Krupp was now beginning to see in the ingot-steel rail a product of far reaching importance, and as early as 1861, when the Bessemer works were still at their outset, he started energetically propagating it through the medium of his representatives. A large rail-rolling mill was prospected, and in the old groove rolling mill temporary rail rolls were inserted, on which the first Krupp's ingot-steel rails were rolled by way of experiment in 1862. It was then no easy matter to procure a sale for them to the administrations of railway companies. Only a short time previous had puddled steel become generally recognised as a material for rails, and most railways were, as one may well conceive, averse to again undertaking fresh experiments with an unknown raw material. Alfred Krupp who was the first in Germany to place Bessemer steel rails on the market had, consequently, great difficulties to overcome, and was obliged to furnish a 10 years guarantee in order to obtain his first orders. Later, a 5 years guarantee for the life of steel rails with a fourfold efficiency in proportion to iron rails was given. At the outset the sale proved all the more difficult, as other Bessemer works began to quickly spring up, and to offer keen competition to Krupp's rails. Mistaken ideas and an improper treatment were also the cause of detrimental effects at the outset; the railway companies wanted to obtain an unjustifiable advantage of the increased strength of the ingot steel by reducing the weight, without taking into consideration the increased load on the railway track; faulty shapes and an improper treatment also of the rails brought about an incorrect idea of their efficiency. But Krupp being used to these occurrences, his confidence was not shaken. Besides the German railways, Dutch, Swiss, French and American railways soon became to be purchasers of rails, and when a great depression in trade threatened to be the cause of closing down the rail-rolling mills in 1868, a large order was received from the Eastern railway of France which enabled work to be continued. The first rails made from Bessemer steel, which were supplied in small quantities in 1863 to the Bavarian State railways and to various other railways, had still been manufactured at an outside rolling mill, but as early as the ensuing year Krupp's own rail-rolling mills, designed and built in the Cast Steel Works, were started. They consisted of two three-high mills, driven by a 400-horse power steam engine, and had for that time a very considerable capacity of output. At first the manufacture of rails occupied considerable time and necessitated great expense. The castings were rough-forged octangularly under steam hammers, then drawn out into square-sectionned rail blooms seven inch thick, in the old grooved rolling mill or under the hammer, divided in suitable lengths, and then only, after once again being heated, rolled into definite shape. This was a very troublesome process, but in the Cast Steel Works, where even at that time a number of heavy steam hammers were available, and the value of a thorough forging to improve the quality of the steel was recognised, this method of working seemed the most appropriate one. Even at that time, it is true, Alfred Krupp alluded to the great expenditure and demanded a curtailment of the forging work, supposing that by so doing, it would not be at the expense of the quality of the material. His proposals for improvements, however, being contrary to the conservative views of Eichhoff, who would not see the rough-forging work suppressed, fell through. When the cost of the production of rails rose considerably at the beginning of the 'seventies in consequence of the sudden rise in the price of coal and pig iron, and in wages, Krupp referred to his previous proposals. He pointed out, with very good reason, that in England rail ingots were no longer rough-forged in any Bessemer works, and gave explicit instructions for fresh experiments to be made with a view to rolling the rails direct from smaller ingots. Owing to the works being fully occupied and having no time left for such experiments, his wishes were again not acceded to, but in the subsequent years he continually suggested the simplification of the manufacture of rails and on one occasion said:—"The completion of the individual rail in one heat without forging has ever since been the 'Chimborazo' of my wishes." This shows that also at that time, when his position at the head of the rapidly growing works more and more prohibited him from going into details, he still kept a sharp eye on the main and essential requirements of the various branches. It was not until the industrial crisis of 1874 that, forced by sheer necessity to the greatest economy, new working methods were introduced, and at that time—in fact only after Eichhoff had left the firm—his old wishes with regard to the modernisation of the Bessemer works and the manufacture of rails were fulfilled. A large blooming mill with the necessary furnace plant was built, the finishing mill was reconstructed, and the manufacture of rails considerably cheapened. The position of Krupp's works in the competitive struggle which began in 1874, was considerably strengthened by these measures. Owing to the rough-rolling of the rails, the hammers were in fact deprived of their principal work, and great exertions were necessary to keep then some at least at work by orders for big forgings such as stems and stern posts, &c. About this time the last helve hammers, which had become obsolete, were pulled down.

A new sphere upon which Krupp ventured with great hopes after taking up the Bessemer process, was the manufacture of steel plates and all the products made from them. As early as 1860 he had resolved to erect a large new plate-rolling mill for cast-steel plates up to 12 feet wide. By so doing he had in view, above all the manufacturing of large steel plates for boilers, which were to have only one riveted seam, viz at the top. He soon began to consider the manufacture of ship's armour plates as well, and in 1862 commenced building a large plate and grooved rolling mill, the first half of which was set to work in 1864 with a 1000-horse power steam engine, and a trio of cast-steel rolls of a length of seven feet, which was intended to produce sheet and plates up to 200 millimeters in thickness. In the meantime armour plates—as experimental plates—had been forged out of crucible steel. They were tested at the shooting trials in Antwerp in 1863, but did not prove efficient. This experiment was the cause of rousing in Alfred Krupp a strong and subsequently practically insuperable mistrust in the use of hard steel plates for armour purposes. True to his principles not to introduce a new product before he was convinced of its merits, he maintained an attitude of reserve with regard to the question of ship plates and armour plates and in the meantime endeavoured, conjointly with Eichhoff, to solve the problem of material by employing a tough steel similar to the Danemora iron which is refined by means of charcoal. When the suggestion was put to him by one of his friends to offer Bessemer steel as armour plate and building material for the Prussian corvettes, the construction of which was deliberated at the time, even if it should necessitate heavy outlay, thus acquiring the fame of having been the creator of the first ships built of steel, he declined referring to his former experience:—"Strange to say, it has been proved that whilst for smaller dimensions with the same quality of material, cast steel is far superior to the best iron in point of strength for the manufacture of cuirasses, boilers and the like, it does not merit the same preference to iron in the manufacture of armour plates. The mildest crucible steel is even to hard for the dimensions to be reduced with safety and therefore the application is not practicable, as without this advantage it would be far too expensive." The home sheet-iron industry at that time not being up-to-date, he recommended building the ships of English or French sheet iron, and concluded with the characteristic turn:—"If I am able later on to supply better material, I shall come forward. Meanwhile progress will continue steadily, and the end aimed at requires time."—The experiments with armour plates were again resumed in 1867, but again proved a failure, so that Krupp said in a discontented manner:—"I won't hear anything about armour, and still less of a plant for it, if there is no guarantee given for orders." This was a stipulation which he made for every new plant, and he attributed the great development of the firm above all to the observation of it. He was convinced that only by making experiments in this direction on a small scale he would gradually pave the way to success.—Not for boiler plates either did Bessemer steel prove so successful at the commencement as was anticipated. In spite of this Krupp did not abandon his intention of taking up the manufacture of plates and steam boilers. In 1864, at the same time as the completed rolling mill, the newly built boiler shop was started with 164 men, and in the very same year turned out the first steam boilers, the plates for which of course were procured from elsewhere. Then for some years wrought iron, crucible and Bessemer steel plates were rolled alternately. The large boiler plant of the puddling works II in the southern quarter, consisting of 28 boilers, was built in the firm's own boiler shop; since 1867 steel field-gun carriages for Krupp guns were also manufactured there, at first with riveted-on flange, later on pressed from one piece with the flange.—Krupp had already become acquainted with the construction of locomotive boilers as early as 1864 by making the separate parts, *e.g.* he supplied the cast-steel stiffening rings for connecting the boiler to the smoke box. He had these rings made in unrivalled strength in his tyre-rolling mill, similar to his seamless wheel tyres. The first complete locomotive boilers were made in the Cast Steel Works in 1868, and were supplied to Hartmann at Chemnitz. These orders increased in the succeeding years, ship boilers were also added, and in the seventh year of its existence, the boiler shop had already turned out its 100th steam boiler. Later on the activity of this plant, which in 1872 was transferred to a new building, and connected with a plate forge and mechanical workshop, was increased by the execution of structural steel work, *e. g.* roof constructions, bridges, gasometers and such like.

In the meantime also the problem of the material which had first caused such great difficulties in the manufacture of steel plates, had been furthered to a considerable extent. Bessemer's invention which had indeed solved the problem of gross production, but not entirely the problem of quality of mild steel, had been followed by other successes which towards the end of the 'sixties once more directed the production of steel into another channel. As far back as 1850 the old reverberatory furnaces in the metallurgical workshops had now and then been improved by employing gas firing. Then followed Friedrich Siemens' revolutionising invention of regenerative heating which by preheating gas and air enabled far higher temperatures to be obtained than formerly, and which began to take effect in the foundry practice about 1860. In their English patent of 1861 the brothers Friedrich and William Siemens already drew attention to the possibility of considerably raising the heat in the melting furnaces, and of obtaining cast steel in arched hearth furnaces by the aid of regenerative gas firing. Some years elapsed with the experiments to ascertain a sufficient refractory building material for such hearth furnaces, and also the best shape of furnace and the proper charges. Through the efforts of the brothers Martin in Sireuil these experiments were conducted to a satisfactory issue. In April of 1864, after many experiments, they succeeded in producing the first utilisable ingot steel on a large scale in the hearth furnace, this introducing a new era for the steel industry which was in no way inferior to the result of the Bessemer process. The general attention of metallurgical experts was called to the Martin process at the Paris International Exhibition in the year 1867, and its practical application dates from this time.

Krupp in accordance with his undeviating determination to be the leader in the manufacture of cast steel, had not waited so long. He had shown interest in the system of regenerative heating from its infancy, and as early in 1863 had entered into direct relations with Friedrich Siemens. He had followed with great interest the brilliant progress of the brothers Werner, William and Friedrich Siemens and reposed an unlimited confidence in their technical talents. "If Siemens makes a promise," he once wrote, "he is the very man to keep it." From 1864 the first experiments for the introduction of regenerative gas firing took place in two carefully secreted testing houses of the Cast Steel Works, both for crucible furnaces and for the openhearth process. Young chemists and metallurgists, having received a polytechnical education, were appointed for this work, and although the recipes and the skilled practice of old experts were still believed in for a long time, scientific metallurgy also by degrees found acceptance at the Cast Steel Works. In this respect Krupp's superiority over his fellow workers was evident; although he had grown up with them chiefly as their instructor, and in the empiric way of thinking, he never shared their mistrust against what was new, on the contrary, where it was a matter of introducing a new method, he was always for favouring fresh ideas, and many remarks which he made at that time proved that he had quite determined to be the first on the field to introduce every new method pointing to progress. He especially set great hopes on the application of the regenerative heating for the crucible melting process. "If the new melting method goes well," he wrote at the commencement of the experiments "the whole steel foundry will then of course be reconstructed." Although many difficulties and disappointments were encountered, one arrived quickly at a successful result with the melting and refining of steel. The first experiments were conducted in accordance with those of the Frenchman Sudre who had obtained steel by melting down spiegel and wrought iron in the hearth furnace as early as 1860, at Montataire. With Krupp, the first experiments had proved a failure owing to insufficient heat being obtained to bring the charges to the necessary melting temperature. The wrought iron partly remained pasty, the steel was not sufficiently liquid and the castings remained porous. It was not until 1868 that a change for the better set in. William Siemens offered Krupp his new and considerably improved regenerative gas furnace, and his process for the preparation of steel, which he had invented a short time previous to this, for work on a large scale. By improving the Martin furnace, Siemens had succeeded in making it possible to melt down cast steel in large quantities from a mixture of steel scrap and pig iron. Krupp took Siemens' proposals very earnestly. "The news is extremely interesting,—this may be the means of bringing about a mighty evolution in the manufacture—we must follow the matter up .... not let it slip past us—be the first in the field if it goes well." He made corresponding arrangements with Siemens and the brothers Martin, and about the middle of the year 1869 the first Siemens-Martin furnaces of the new construction was started in the Cast Steel Works. Like the Siemens furnace it worked with charges of pig iron and steel scrap, and also the shapes of the gas and draught flues were made in accordance with Siemens proposals. The furnaces proved a success and supplied from the very outset 96 charges of steel. At the beginning of the year 1870 the furnace reconstructed according to particuliars furnished by William Siemens who had been continuing his experiments in the meantime, and then kept on working.

Thus the initial experiments were terminated, and the plant of the first Martin works with twelve furnaces, in the southern quarter of the Cast Steel Works, introduced a new paragraph in its history in 1871. The Martin works were situated at a considerable distance from the old centre of the factory, and in the neighbourhood of a windmill which Krupp had years past prophecied would in the future be the centre of his works. In accordance with the principle, which had gradually become traditional, of keeping new instalments secret, the new plant was called "Testing House H". The Martin works had two rows of six furnaces between which a long casting pit was situated. An overhead travelling crane ran over the casting pit for carrying the ladles and moulds, and on the narrow side of the building the gas producers or generators were situated. At that time the furnaces had a capacity of four tons; now-a-days 25 to 45 tons of Martin steel can be melted down. The first furnace of the new works accomplished its first charge on September 28th of 1871, and soon afterwards all six furnaces on the one side were in full working, whereas the second row was not built until later on. The regenerators through which the furnace gases passed off in order to give off their heat on the latticed brickwork and through which air and gas passed in order to be heated on the red hot masses of stones, were situated under the furnaces. The flames entering the hearth were led in such a manner that their effect was directed and reverberated as much as possible towards the middle of the hearth by means of a saddle-shaped arch. About 200 kilogrammes of English pig were first put into the furnaces, when this had melted a threefold quantity of Bessemer scrap after which up to two tons of steel scrap, rail ends, runners from wheels and such like were added, and finally an additional charge of some 300 to 600 kilogrammes of spiegel in order to regulate the carbon percentage. The Martin plant thus principally worked up large quantities of scrap *i. e.*, the waste produce from the crucible and Bessemer processes, and the mechanical workshops, with comparatively small additions of pig iron, producing in turn a far better steel than the Bessemer works. In the first complete year of working, the production amounted roundly to 9000 tons, and as early as 1874/75, to 19,500 tons. The cost of production became less and less, and at times went below that of Bessemer steel. At first Martin steel was principally worked up into tyres, and soon experiments were made to cast railway wheels, which had hitherto been made from crucible steel, in moulds from the Martin furnace. This new idea proved such a success that the wheel foundry was soon entirely transferred to the Martin works, which step necessitated enlarging the latter by a moulding hall with drying ovens, &c. As with Bessemer steel at the time, experiments were now made to employ also Martin steel for most of the products which had hitherto been made of crucible steel. A series of these articles, for instance axles and heavy crank shafts, springs and tyres, succeeded to all expectations, and these products, of sufficient tensile strength, could be brought into the market cheaper than before. For other objets, especially in the manufacture of guns, the old experience here was once more made that, if exposed to highest strains, no material could enter into rivalry with crucible steel in respect of purity and strength. The experiments with the Martin furnace trying to give the steel the properties wanted for special purposes already by the composition of the charge, which trials necessitated to examine the results by thorough tests later on, led to an increased application of scientific methods and appliances on which rest modern metallurgy.—As now new difficulties arose to procure steel scrap in sufficient quantities for the increased production, repeated experiments were made to develop other methods. Alfred Krupp set great hopes on Siemens' new process of reducing iron ores in a revolving furnace with producer gas firing, the so called precipitation process. He anticipated from this process, as formerly from the Martin and Bessemer processes a complete revolution in the manufacture and incessantly urged furthering Siemens' proposals. The tests were carried out in 1873 at English works with Krupp's ores and coal, but did not give the result that was expected. Most of the impurities of the ores passed over to the slag, but the copper and part of the sulphur remained in the steel which was besides made impure by small particles of ore, coal or slag. Thus the new Siemens' process was inapplicable for the ores and coal at the disposal of the Cast Steel Works. In spite of this Krupp did not abandon hopes of finally succeeding. "It is in fact possible," he wrote, "that Siemens will find more difficulties than he anticipated. Inventors are frequently over-confident, however, Mr. Siemens is a man, who has accomplished great things by perseverance, and I repose every confidence on him even though the problem should not be solved for some time to come." From 1875 the new Siemens ore process *i. e.*, the introducing of certain iron ores with a charge of pig iron, was then successfully carried out at the Cast Steel Works. The ore had a fining effect on the molten pig iron, and under violent ebullition of the pig abundant quantities of slag were given off; good steel for rails and tyres was successfully made by this process. A combination of the process with the older mixing process was then introduced, the refining process being accelerated by a certain addition of iron ore to the former customary charges. The production of various kinds of steel for definite purposes of use, and with stipulated properties was further developed. In connection with this work the name of the metallurgist Dr. Bender, who prior to the inventions of the brothers Martin had participated in the first experiments tending to produce ingot steel in an open hearth at Montluçon, and who had a large and meritorious share in the development of the first Krupp Martin works. The many experiments and studies relating to new methods of refining steel, and to the composition of the charges, were carried out in the course of years under his guidance in the Martin shop I, which from this fact justly bore its name "Testing House". These experiments will have to be reverted to later on as they are in close connection with Krupp's work and the hope he cherished during the closing years of his life.

Besides the production of steel, the efficiency of the iron foundry connected with the Cast Steel Works had also developed considerably. At the beginning, Alfred Krupp bought from other foundries the cast iron required for his products, and also for the erection of his own workshop machinery. Only a pattern-makers' shop was erected as early as at the beginning of the 'thirties in order to be independent for the shaping and construction of parts of machinery. The heavy castings for the first steam helve hammer built in 1852, were still made at the Gutehoffnungshütte in Sterkrade. The growing requirements of the factory in foundry products then necessitated the firm establishing its independence in this direction. In 1854 the first iron foundry was built on a small scale at the Cast Steel Works, and was set to work with a furnace of an hourly output of 1800 pounds, and with a 12-horse power steam engine for the blast. A new pattern-makers' shop was likewise built, and in 1855 the iron foundry employed as many as 50 men. Many enlargements were made in subsequent years and a large number of heavy pieces were even at that time turned out of the iron foundry, among others the anvil block, various anvils and tups made for the helve hammer, weighing 140 hundredweights, and erected in 1856. The erection of the hammer "Fritz" with its enormous castings, for that time presented great difficulties. The iron foundry had to be extended in 1859 by two large cupola furnaces with an hourly output of 6000 to 8000 kilogrammes, in order to answer these requirements. The casting of the gigantic "kangaroo standards" for the hammer frame, which was done in March 1860, and the success of which Krupp, who was then staying in Berlin, had telegraphed to him, was eagerly looked forward to. As early as the autumn of 1859, the heavy main part of the anvil block of this hammer weighing 2500 hundredweights—the largest iron casting made up till then at the Cast Steel Works—was cast in the presence of a number of friends of the firm invited as guests. In 1862 were added to the cupola furnaces two reverberatory furnaces each with a capacity of 10 tons, for casting heavy rolls, and in the following year was erected a foundry for small castings with two new cupola furnaces. The manufacture of iron castings for self consumption was now adopted on a large scale at the Krupp works. The iron foundry was kept very busy by the castings of tups and anvil blocks for the growing number of steam hammers, the great number of heavy moulds for the crucible steel and Bessemer steel castings, and later on also for the Martin steel casting, large rolls and standards and housings for the own rolling mills, further, parts of machinery of all kinds, pieces for furnaces, castings for buildings for the uninterrupted enlargement of the works. Up to the middle of the 'sixties the requirement of pig iron for the above purposes as well as for the puddling works and Bessemer plant were obtained by purchase. The excellent brands of pig iron from the Gutehoffnungshütte, the Georgs-Marien-Hütte and the Horster-Hütte were chiefly used for foundry purposes, and the other requirements were supplied by the purchase of first class English and Scotch iron. Starting with the purchase of the Sayn works the firm began to buy its own mines and blast furnaces, and thus to produce the pig iron in its own plants.

# EVOLUTION AND ORGANISATION.

By hard work which was, however, crowned with extraordinary success, Alfred Krupp had raised the Cast Steel Works from a small mechanics' shop to the largest and most diversified creation of industry on German soil, to a mighty combine of mechanical shops, forges, iron works and collieries. At every step he had had obstacles, incident to the nature of his undertaking, to overcome; the evolution of the factory was also considerably influenced by the general fluctuations of economic life. Periods of rapid, even headlong advance, alternated with years of slackness or retrogression, which delayed success. The effects of each industrial crisis were, it is true, very greatly modified by Krupp's adherence—as far as possible—to the principle of not dismissing his workmen, and of straining every resource, either by working for stock or by enlarging the shops for future needs. Still the rises and falls in the state of trade are reflected, on the one hand, in the spasmodic increase of the number of men, and on the other by the enlargement of the shops. The evolution of the outward aspect of the works between 1848 and 1874 took place in three periods of vigorous growth. The first coincides with the company-founding bubble of the 'fifties, which ensued after the discovery of the Californian goldfields and lasted about from 1850 to 1856. This period raised the number of workmen in the Cast Steel Works from 250 to over 1000, and caused the erection of the now vanished nucleus of the factory on the site where the present Administration Building stands. The shops put up at that time:—the forging and rolling mills, the mechanical workshop I, the puddling shop, the iron foundry and the tyre-rolling mill,—were principally provided for the manipulation of railway rolling stock, and by the simultaneous enlargement of the crucible-steel foundry, the area covered by buildings on the grounds was increased from 0·4 hectare to 3. The machinery employed at this period was very simple, most of the lathes had wooden beds, the cranes were worked by hand, the biggest steam hammers were made in the antiquated form of the helve hammers. But the forward march of time produced new forms more suitable to the various purposes. The new tyre-rolling mill was a masterpiece of engineering, the machines for centering the tyres and for pressing the wheels on to the axles were worked by hydraulic power. By far the greater part of these appliances, and even some of the steam engines were designed by Krupp himself and made in his own shops. This sudden rise was followed by a depression of trade which lasted several years. Alfred Krupp utilised the time by preparing for the next extension, the approach of which he clearly foresaw, and thus kept his men at work. At the end of the 'fifties, a new and much more vigorous upward movement set in; it lasted till 1866 and raised the number of men from 1000 to 8000. Gun making was now added to the production of railway material, and the scope of the factory began to cover new ground. A period of almost feverish activity in building corresponds to the rapid increase in the number of hands. The number of mechanical workshops rose to four, besides which the two first gun shops were built. Although the mechanical and gun shops formed for some time one department, with a common management and account-keeping, still a division of labour was gradually effected, in so far that gun making was quite given up in mechanical workshop I, which was henceforward entirely used for the making of peace material. Various branches of gun making were distributed among the other mechanical shops, besides this in mechanical workshop II the turning of long heavy shaftings and crank axles, and the manufacture of sets of wheels was carried on, while in mechanical workshop III cranks and axles were trepanned, and in IV big machines were erected. The increased sale of railway material called for another and larger tyre and rail-rolling mill, an extensive plant for wheel making and the first turning shop for sets of wheels. The hammer "Fritz" was put up, the old forges considerably enlarged and a new gun-forge building erected. The boiler forge and the plate-rolling mill came into being, and the increased production of steel necessitated further extensive additions to the crucible-steel foundry, besides the building of the Bessemer work. The first steel shops on the south side of the works arose, a larger crucible steel foundry, a puddling shop, a wheel foundry, and a new spring shop were put up there. The appliances of the workhops were also correspondingly improved. By 1866 the number of machine tools in use was 287. The number and hauling power of the cranes had risen. In 1859 the first overhead travelling crane was put up in the mechanical workshop I; in 1861 the first steam crane for the hammer "Fritz". In the large middle bay of the mechanical workshop IV, which surpassed all the other shops in extent and equipment, a steam overhead crane, with a hauling power of 1000 hundredweights was erected, to move the heavy pieces of rolling mills, steam hammers, blowing and rolling machinery, which were erected here. The demands made by gun making also contributed to develope the building of machine tools. Rifling benches were put up, and trepanning machines, which no longer scooped out the bore in the form of shavings, but cut a solid core out of the tube, in one piece, which could be afterwards worked up for other purposes. The number of steam hammers rose from ten in 1857 to fifty in 1868, their weight of tup was increased tenfold. In 1865 there was a total of 100 cranes with a total hauling capacity of 950 tons.—Another depression of trade which lasted till 1870, forced a slight curtailment of work at the factory, but did not check its evolution in any considerable measure. On the contrary, Krupp sought by adding to and altering buildings, enlarging shops, improving the manufacture of wheels and mounts, to make head against the depression. The laying out of the first proving-ground in the factory, the building of a number of boiler houses and coke ovens belong to this time; two new gun shops were also built, as this branch of production was thriving and helped to tide the works over the depression. After the victorious close of the war, a new period of rapidly-increasing activity set in; the number of men employed at the Cast Steel Works, which had temporarily fallen to 6000, quickly regained its former standard, and then surpassed it, till shortly before the crisis of 1874 began, it had attained a maximum, with upwards of 12,000. The buildings put up at this period, too, kept pace with the output. Large shops, adapted to the rising demands, both in their appliances and extent, were erected for the manufacture of wheels and sets of wheels, also for gun carriages and mounts. New Bessemer works, puddling and steel shops arose, and the forges underwent further extension. The open-hearth steel shop, the new boiler forge, big boiler houses, repairing shops, and numerous auxiliary shops were built, and the area covered inside the factory's grounds rose from 13·35 hectares in 1865 to 35 in 1873. This time is marked in engineering by another great increase of steam hammers, 79 with a total weight of tup of 206 tons in 1875, and other appliances among which were the first cable crane and hydraulic slewing crane. Hydraulic motive power was now also applied to the riveting machines and presses. The economic depression of the following years did not favour the utilisation of these abundant resources, but it promoted their modernisation in the direction of cheapened and rapid production, by the severe pressure of competition. In this state of perfection the workshops proved equal to supplying all demands, even after the market had improved, and until Alfred Krupp's death, no important additions to the factory buildings were made.

With the growing extent of the works, a number of auxiliary departments had naturally originated. First on the list, is the steam-engine boiler plant required for supplying the works with motive power. The erection of his first steam engine had once been a decisive turning point in Alfred Krupp's life, marking the transition from the narrow surroundings he had inherited, to the big combine he himself created. For many years, this old beam engine, dating from 1835, with its two one-flue boilers, had kept the works going except for the help of a few auxiliary engines added in 1850. Then with the first considerable enlargement of the works, a great increase in the number and size of the engines began. A 40-horse power driving engine was erected in the mechanical shop I, which drove all the machine tools in that departement for 36 years, and was only replaced by a modern 100-horse power engine in 1888. In 1852 a 100-horse power engine began driving the first grooved and spring-rolling mills; another, two heavy helve hammers, and in 1856, a third of 200-horse powers, was started in the tyre-rolling mill. This occasioned an increase in the number of boilers, before 1851 there were only two, in the next year, four; in 1855 as many as ten, and after the puddling shop was built, in 1856, and its waste gas utilised for the generation of steam, there were 18. The boiler house B, at the side of the puddling shop, with its ten boilers, was the first central power station in the factory for the distribution of steam. A small part only of the steam was used for the driving engines, the greater part was needed by the hammers, which at that time rose rapidly in number and power. Thus the next great increase of steam boilers in 1860—when the number was doubled—was to provide a power station for the hammer "Fritz". The great development of shops and rolling mills which now began, caused a proportionate rise in the number and power of the steam engines. In 1862 the first twin steam engine was set up, in 1866 the number of driving engines had reached 110, with a normal output of 7250 horse powers. The boiler plant installations rose simultaneously to 12, containing a total of 140 steam boilers. The endeavour to utilise the waste heat from the puddling and heating furnaces and the coke ovens for the generation of steam, led to the combination of the boilers in larger and larger groups, and to the distribution of the steam from central stations, according to requirements, whereas hitherto the boilers had stood singly or in small groups arranged according to the amount required for consumption. In 1862 a boiler house for 16 double-flue boilers was built, and in 1863, a much larger one with 50 similar boilers; after this, the erection of the old one-flue boilers was gradually abandoned. At first the steam pressure amounted to 2½ atmospheres, it rose by degrees to 4 atmospheres, and after 1864, it went on rising till in the 'seventies it reached 7 to 8 in some of the boiler plants, a limit which has only been surpassed in modern times by building considerably stronger boilers. After 1870, the number of engines, which in the second half of the 'sixties had been almost stationary, began once more to increase, by 1874 it had risen to 180 driving engines, with a total yield of 11,000 to 12,000 horse powers. In that year the erection of the first compound engine with injector condensation took place, whereby a new departure was made in the structure of driving engines. In consequence of the simultaneous increase of the steam hammers, the number of boiler installations rose still more rapidly; in 1874 there were 224 steam boilers in 26 boiler houses, with a heating surface of 13,730 square meters. The efficiency scarcely exceeded this figure before Alfred Krupp's death, although the number and power of the machinery during that time were considerably raised. One consequence of the substitution of modern hammers and machines for antiquated ones, was a great reduction in the consumption of steam, and besides this, by appliances for heating the pipes, by chemical purification of the feed water and similar improvements, it was possible to generate steam more economically, so that the output of the boiler plant could be raised considerably without augmenting the heating surface.

Another matter of vital importance to the factory, in close connexion with the boiler plant, was the water supply. The first mention of a regular water supply occurs in the 'thirties, and relates to the sinking of several wells, the water from which was pumped, either by hand or machinery, into the hardening shop and the boiler of the first steam engine. The first tank was also put up in the hardening shop. This supply was insufficient even in those days. If heavy rolls had to be hardened, a process which had to be effected with flowing water, the supply was cut off every where else, so as to carry all the water to the hardening shop, and to the boiler feed pump. Alfred Krupp, in 1871, still remembered how "when the well had been pumped out, the water was carried from the pond in buckets and poured into it, because the laying of pipes was too costly an affair." The pond here mentioned, was near the hammer "Fritz", and was long used to supplement the water supply in the factory. It was afterwards included in grounds laid out round about the Garden House and the Visitors' House, and only at a recent date has been sacrificed to the increase of buildings on the premises. All through the 'forties the state of the water supply was very unsatisfactory, neither the wells nor the springs were sufficient to meet the requirements. Besides, the supply sometimes suffered greatly from the varying level ef the water in the neighbouring coalmines, which caused disputes and even law suits. In 1853 Alfred Krupp secured a supply by making a contract with the colliery Sälzer & Neuack for the superfluous water from the various pits, this was cleansed in a settling reservoir made at the time and taken through conduits to the factory. As an indemnity the colliery took its supply of lighting gas at reduced prices from the Krupp gas works. Inside the works part of the water was taken into the shops through pipes or by pumps, while part of it was driven into two elevated tanks. During the 'sixties the collieries of Hagenbeck, Schölerpad and Hoffnung were connected with the Sälzer reservoir, so as to bring their superfluous underground water to the works also. A large central water station, with plant and machinery, which since then has been greatly enlarged, still distributes the collected water of the collieries to the shops. But it had long become necessary to find other sources for the water supply, as, by the end of the 'fifties, the colliery water was already insufficient, besides which it was too hard, and, in spite of cleansing, too dirty to be used for feeding the boilers. The sinking of great artesian wells was begun in 1860, these were to supply more suitable water for the shops and for domestic use. A boring 46 meters deep was made outside the crucible steel plant, from which a long gallery was driven to open up the springs in the marl formation. A tower 60 meters high with a large elevated tank was erected over the boring. This water works is still in use, but it supplies a very small proportion of the present water consumption. For a time the town of Essen helped the works out with large quantities of water through its water pipes, and in 1875 an extensive water works, the third belonging to the works, was finished and started on the Ruhr, and is still in full work. It was at first equipped with three big English beam engines, which pumped the water up into a reservoir lying on the heights of Bredeney, at an elevation of 140 meters, from which it is conducted in pipes down to the factory. After 1880 the Ruhr Water Works were considerably enlarged and at present they supply about half of the water used in the Cast Steel Works, which in 1910/11 amounted to 19,000,000 cubic meters. Another water works, erected at the outlet of the Wolfsbach valley near Werden, in 1901, supplies about one-fifth of the water consumed, from a number of artesian wells in the bed of the valley. This water, unlike that of the Ruhr, is almost entirely free from bacteria.

The gas works, which also developed from small beginnings to their subsequent great efficiency, rank as the third auxiliary force of the Cast Steel Works. They were begun in 1856, from plans drawn by Ritter, the Duisburg civil engineer; an English plan submitted at the same time was rejected by Krupp. The little gas works only comprised two ovens with five retorts each, the indispensable appliances and a gasometer of 520 cubic meters capacity. The gasometer of this first gas work is preserved as a memorial of the early days of the subsequent large works. As early as 1860 these gas works reached the limit of their yield, with 100,000 cubic meters, and five new ovens and a gasometer of double the size of the older one had to be built. Two years later another five ovens were put up, which were all fitted for the then usual grate firing. But in consequence of the great extension of the factory during the 'sixties, these could only for a short time meet the demand, which amounted to more than a million cubic meters in 1864, and Alfred Krupp, perceiving that piecemeal additions could not serve any permanent end, proceeded to build entirely new gas works, corresponding to the new order of things and the modern improvements that had come into use. These works also underwent many alterations and extensions. In less than two years the yearly output rose to 2½ million cubic meters, and by 1874 to 7 million. In this year a radical innovation was made by the use of regenerative gas fuel, which was adapted to all the ovens in place of the old grate firing and reduced the consumption of fuel to one-half. The gas works at the Cast Steel Works, with those of Cologne, Munich, Dantzic and Dessau, were the first who made use of this improvement in Germany. Among the later new buildings, mention must be made of a huge gasometer of a capacity of 37,500 cubic meters, built after the design of the well known Professor Intze, of Aix-la-chapelle, and which was put up instead of the old meter of 5000 cubic meters. On account of the insecure nature of the ground this new meter was erected over an iron water tank with an outside coating of masonry. The old meter which stood on this spot had sunk so much and so unevenly, owing to the ground giving way in consequence of coal mining that it had to be pulled down. Thanks to its improved design the present erection has so far successfully resisted the movement of the ground. After the introduction of incandescent gas it was possible to utilise, for the lighting of the factory and the colonies, the coke oven gas from the colliery of Sälzer & Neuack, which passed into the hands of the Krupp firm in 1901; by this means the demand on the gas works was reduced. The working of the latter, which had been enlarged in course of time till it comprised 40 ovens with 360 retorts, three huge gasometers and extensive auxiliary plant, was gradually reduced till the works quite ceased, in 1911. The greater part of the gas consumed in the Cast Steel Works, which reached a total of 17,660,000 cubic meters in 1910/11, is now supplied from the coke ovens of the above mentioned collieries, and in the winter coke-oven gas is obtained from mines in the neighbourhood, by the mediation of the Town Gas Works. A system of mains 140 kilometers long at present, distributes the gas, a system of secondary pipes, 330 kilometers in length, connected with the mains carries it into the various buildings, besides which pipes, 7·5 kilometers in length, convey the gas to the gas and water works at the Hügel.

An institution very near and dear to Alfred Krupp's heart from the very beginning of his activity was the protection of his factory against the danger from fire. The thought that a fire might break out and destroy the fruits of his whole life and deprive the thousands. for whose wellbeing he felt himself responsible, of their bread, filled him with horror, As early as the 'thirties he established a regular service of watchmen, and as the buildings increased in extent, the number of these men was added to, and they were placed under strict supervision. In the 'forties a regular Fire Brigade was formed, fire engines and extinguishing apparatus were distributed among the various shops, and certain men were drilled in the use of them. When the water supply was increased at the Cast Steel Works, one of Krupp's chief motives was to provide for security from fire. For this purpose, at his express wish, the water tower of the central station was built 60 meters high, so as to get sufficient pressure at the hydrants to combat the flames with success. Such precautions have, doubtless, contributed much to prevent destructive fires in the factory; still the first conflagration which broke out on July 15th, 1865 and destroyed a part of gun shop I and mechanical workshop III, proved that the measures taken so far to prevent such disasters were insufficient. So this fire gave rise to the institution of the professional Fire Brigade at the Cast Steel Works, which was organised on the model of the Essen Volunteer Firemen's Brigade. Professional fire brigades were at the time still very rare in Germany, only three towns:—Berlin, Königsberg and Stettin could boast of one, and in industrial works there was not a single one. The fire brigade of the Cast Steel Works began its career on the 1st January 1866 with two batches of six men each, in February four more batches were added. A second great fire, which broke out 1871 in the crucible room, destroying the building with many of thousands of valuable crucibles, caused a further extension of the fire brigade. The hand-drawn engines which had been first used, were given up, and replaced by engines drawn by horses, which could cover the distance more quickly; the personnel was also increased, in 1873 the strength of the fire brigade was as much as 70 men, to whom also the police service of the factory was entrusted. By an order issued in 1869, the fire brigade were empowered to call out as many men from the shops as they required to help them. The service of night watchmen was also increased as the factory extended, and in 1873, 160 men were employed in this department. By and by auxiliary fire brigades were established as well as the chief brigade, so that prompt help might be given, whenever a fire broke out. The number of these smaller fire stations is at present five. The strength of the brigade has been augmented by this time and now comprises 121 firemen, 19 subordinate officers and 3 officers. Thus the Krupp fire brigade is inferior only to those of some of the largest German towns. In 1904 the first steam motor fire engine was put into use. Soon after motor cars were provided for the men, and finally a rotatory ladder driven by a motor. Two gas fire engines and a tender are ready at the first alarm, and certain reserves for the second alarm. The activity of the Krupp Fire Brigade is not limited to the Cast Steel Works, it has to give help in case of fire at the Hügel, in the Krupp colonies and at Essen-West. There are 121 automatic fire-alarms to call out the brigade; besides which it can be rung up by any telephone belonging to the factory. For first aid in emergency, before the fire-engines arrive, 486 hand engines and 643 fire cocks are available on the premises of the factory.

While the principal producing shops and the auxiliary departments above described, were thus being rapidly put on a modern footing, the means of transport in the Cast Steel Works were still very much behindhand. Even at the end of the 'fifties not only the bringing up of raw material, and the despatch of manufactured articles, but also the means of transport in and about the factory itself were primitive and wasteful. Only the coals from Sälzer & Neuack could be brought in on a narrow gauge tramline along the Altendorferstrasse, while the delivery of coal from the colliery Graf Beust near Essen—a rather large quantity at that time—had to be drawn by horses in long lines of carts through the streets of the town, and the pig iron which came from other places was forwarded utilising a horse tramline connecting the Cologne-Minden railway with the Waldthausen pit near the Cast Steel Works, whence it was carted to the works by day-labourers. Till the middle of the 'sixties the only means of transport inside the factory were trolleys drawn by men or horses. Even in 1864 heavy castings were dragged out of the crucible-steel shop on a trolley to the hammer Fritz by several hundred men. Iron plates were laid over the worst places of the uneven roads in the factory, but in spite of this crowbars had often to be resorted to in transporting heavy loads, so as to get them along. In spite of all these difficulties, it was a long time before Krupp made up his mind to establish an efficient junction with the Cologne-Minden line, which since 1847 had passed the factory at no great distance on the north. He had grown up in a district, and at a time, when all heavy loads had to transported by carts and horses, the days were, indeed, not very long past "when one horse could manage all the transport of the works comfortably". Horses and men had brought his first machinery, his heavy oak hammer axles and handles, the boilers and castings required in the factory from greater or lesser distances, and perhaps he considered this means of transport as best suited to the ground on which the works stood, which was still very uneven. The story goes that once, when it was suggested to him that he should at length get a connexion with the railway line, he said:—"Nay, I would rather build myself another workshop." The instinct of producing and striving onwards was too deeply implanted in his nature, for him to divert time and money to secondary purposes which he did not at present consider urgently necessary. The junction with the railway line only became imperatively necessary at the beginning of the 'sixties, when with the evolution of the works the demand for raw material rose very high. The negociations for the building of a connecting line to the Cologne-Minden railway were ended in 1861, but the completion of the line dragged on till Christmas 1863. In the May of the following year the works started their first locomotive and standard-gauge trucks. As early as 1859 a narrow-gauge line had been laid down as a temporary help to the Mülheim-Essen tramline, which had been running since 1853, and by means of which narrow-gauge horse trucks could be brought close up to the crucible steel shop. After the broad-gauge line had been laid in the factory, this junction with the Mülheim-Essen tramline was given up, but the narrow-gauge railway was retained inside the factory and greatly extended between the shops and inside them; in the 'seventies these lines were combined into a system with locomotives. The broad-gauge line was also carried into all bigger shops, so that from 1864 onwards raw materials and manufactured articles could more easily be brought in and taken out. The connexion with the Cologne-Minden railway did not, however, long remain the only one. During this time the Berg-Mark railway from Dortmund via Essen to Duisburg had been opened, this line was also connected with the works in 1865, and now the coal from Graf Beust could be run straight into the works. The conversion of the Mülheim-Essen tramline into a double-track main line in 1867, enabled the Cast Steel Works to form a connexion with the Rhenish Railway. Thus a great circle of railway extended round the factory, connected with the public railways at three points, and with branch lines to all the more important shops. At the points where the main lines touch the factory on the north and on the south, a north station and a south station were built, for collecting and distributing the trucks and making up the trains, and a regular railway system was developed under the management of professionally trained men. This railway system has grown uninterruptedly with the expansion of the factory, and the consequent connexion of more and more places of consumption and production. In 1874, its total length measured 38 kilometers and at the present day 86 kilometers. At the end of the 'sixties the firm owned only 6 broad-gauge locomotives, in 1874, the year of highest development during Alfred Krupp's life, the number rose to 18; it is now 19. On the other hand, the number of narrow-gauge locomotives has increased much more; when the broad gauge was equal to almost all the traffic, there were only 7, in 1890 there were 17, and in 1911 36, with a total of 60 kilometers of line. The narrow-gauge system is chiefly used as a means of transport between the various shops. The total weight of loads which are annually transported on the broad and narrow-gauge lines amounts at the present day to a round sum of eight million tons. Two managing offices each with its own district and staff of about 200 men manage the working and supervision of the lines, two special shops serve for the testing and up-keep of the rolling stock.

From the first, coal took a prominent place among the raw materials needed for working the factory. In order to facilitate the supplying of coals Friedrich Krupp removed the coke ovens and the foundry from the Walkmühle in 1819, to the neighbourhood of the Sälzer & Neuack colliery, outside the Limbeck gate at Essen. He had made a successful application to the mining authorities—who could at that time interfere effectively with the working of the collieries—for a sufficient supply of coals of constant quality from certain seams. The Sälzer & Neuack colliery is among the oldest and most famous in the Ruhr district, it modernised its working plant as early as 1809, by the erection of a "Fire Machine" at the Josina pit, in the southern part of the present Krupp colony of Cronenberg; this enabled them to open up deeper strata; in the 'twenties their annual output was upwards of 20,000 tons while the output of all the other Ruhr collieries together only averaged 8400 tons in 1850. The quality of the Sälzer & Neuack coal, too, suited the requirements of the Cast Steel Works, so that Alfred Krupp as well as his father took his entire supply from this source for many years. The coals were delivered for the most part just as they were extracted from the pit, and were sorted in the works at the washing sheds or the coke ovens. From 1854 onwards the coals were transported from the mine to the works on a tramline. Only at times when there was an unusual run of orders, or when no satisfactory arrangement of prices could be made with the Sälzer & Neuack pits, did Krupp turn to other mines for his coal supply; Graf Beust for instance, which was not far from the works, supplied large quantities of suitable coal at various times. This colliery was one of those which had come into existence in the 'thirties and 'forties, when the Ruhr mining industry had pushed out to the north, and had opened up valuable coalfields under the chalk strata. The gradual exhaustion of the southern seams which lay close to the surface, and the possibility offered by the introduction of steam power for hauling and pumping at great depths, gave an impulse to this movement towards the north. In a short time the deep pits of Schölerpad, Victoria Mathias, Helene Amalie, &c. arose in the vicinity of the Cast Steel Works, so that Sälzer & Neuack could no longer play the dominating part it had hitherto had in the Krupp workshops. The prosperity of trade in the middle of the 'fifties, which sent up the price of coal for a time by 75 per cent, aroused a wish in Alfred Krupp to provide suitable coal for the requirements of his factory with more certainty in the future. A favourable opportunity was offered by his taking over the colliery Graf Beust, which was being worked at the time with insufficient means and a low output, and which was leased by Alfred Krupp in 1864 for a term of 20 years. Krupp immediately invested large sums in rebuilding and enlarging the somewhat dilapidated plant, and succeeded in raising the output from 50,000 tons to four times the amount in a few years. After 1870 the output rather decreased, partly on account of a fire in the mine, partly in consequence of the Franco-German war, and in 1872 the colliery joined in the first coal strike that originated in the Essen coal district. Alfred Krupp was so indignant at this breach of contract on the part of his men, which he considered as a disloyal desertion of the colours, that he wanted to cancel the lease as soon as possible. He only desisted from his purpose, when the men sent a deputation to him. This strike, which was to some extent justified by the general complaints as to the housing conditions, may have influenced the resolve Krupp made at the time, to do something for his workpeople, especially in the matter of dwellings. His unpleasant experiences with Graf Beust decided him, however, not to lean any longer on this one uncertain prop, but to make himself as quickly and completely as possible independent of any resources but his own in the matter of coal supply. This could only be done by the purchase of efficient collieries. The increasing consumption in the factory pointed this way too, for between 1868 and 1872 it had risen from 300,000 tons to 530,000 tons. Another sudden rise of 135 per cent in the price of coal during these years finally decided his resolve to place himself on a firmer footing than hitherto in the question of fuel. Krupp's choice fell on the Hannover colliery near Bochum, which had been opened about 1860, but had been worked under difficulties owing to the quantity of water in the pit, and thus had changed hands several times. Krupp purchased this mine in 1872 for 1,350,000 Talers, and he succeeded here, as he had done at Graf Beust in raising the output considerably by the improvements he made in the plant. The output rose from 140,000 tons in 1872 to 553,000 in 1880, so that Krupp could not only meet his own requirements, but in certain years could put a considerable quantity into the market.

At the same time as he leased Graf Beust, Alfred Krupp began purchasing iron-ore mines as he wished to become as independent in his most important raw materials, *i. e.* ores and pig iron, as he was in the matter of coal. Until the first Bessemer plant was built, he had been able to satisfy his comparatively small wants by purchasing, but when he took up the manufacture of ingot steel, the quality, as well the quantity required rose to a degree that could only be guaranteed for the remoter future by Krupp's becoming the owner of iron works himself. The first step towards this end seemed to be the securing of suitable concessions; as early as 1864, even before Krupp owed one single blast furnace, he had bought about fifty concessions in the Lahn district for which he had paid 542,000 Marks, a very considerable sum for those days. The mines Anna and Eisenfeld which form part of this old property are still working. The foregoing chapter relates how the Sayn iron works with their iron mines were bought, and all the hopes they raised and all the disappointments they caused by the unsuitability of the ore for the Bessemer process. However, the concessions bought together with these iron works have maintained their value, at the present time several mines on the Sayn property are in full work, with a yearly output of 70,000 tons of valuable ore. By the limitation of Sayn iron to the crucible steel process, Krupp was obliged to go further in the path he had entered on, so as to discover ore—if possible German—for the Bessemer works too, and thus to make himself independent of English pig iron. So he continued to purchase. By 1872, a great number of concessions had been bought—some at a very great outlay—principally on the Lahn and the Sieg and in the Westerwald. Most of these mines, as well as those bought with the Hermannshütte in 1871, have long ceased working, whereas those bought with the Johanneshütte, in the Sieg district in the following year are still only partially exhausted. In 1872 the purchase of concessions reached its maximum, nearly 300 concessions passed into the hands of the firm during that year, among which we may mention the high priced but also extremely valuable Stein mines on the Sieg and the Lahn, where the mines Bindweide, Glücksbrunnen, Friedrich Wilhelm and Füsseberg are still hard at work, and will be able to supply the factory's demand for manganiferous spathic ores for the production of Spiegel and steel iron for many years to come.

Alfred Krupp was not satisfied with buying and continuing to work these mines, but as he had done with the leased and purchased collieries, he set to work energetically to enlarge the extracting plant and better the output of the ore mines. The firm took out of its own mines, in 1874, 177,000 tons of iron ore, and this with what was received from the Spanish Orconera Co., soon sufficed to supply the Cast Steel Works with pig iron from Krupp ore and Krupp blast furnaces, and to put an end to the use of foreign iron. Krupp's attention had been drawn in September 1871 to another source which afterwards became of the greatest importance for the Bessemer works. His English friend Longsdon had heard of the discovery of non-phosphoric iron ore in the neighbourhood of Bilbao and Santander, and he now suggested that Krupp should investigate the concessions and eventually buy them. Careful examination having corroborated the first report, the Orconera Iron Ore Co. was founded by Krupp in conjunction with the Spanish firm Ybarra & Co. and two great English iron works, and the opening up of the Spanish mines was immediately proceeded with. Heavy expenses, however, had to be incurred before this undertaking could be made profitable. The port of Bilbao had to be enlarged, a railway had to be built to the mines, the equipment of the mines required a great deal of time and money, and it was not till 1875 that the first modest cargo of ore arrived at Krupp's works from Bilbao. But then the output increased rapidly, and from year to year the investment became more and more profitable. In 1881 the quantity sent from these mines to the Cast Steel Works rose to 100,000 tons and again to 178,000 tons in 1887/88. The quantity of ore supplied by the Spanish mines to the Cast Steel Works during Alfred Krupp's life time amounted to nearly 1,200,000 tons. Meantime the yield of the home mines had, with slight interruptions grown satisfactorily, so that the purchase of pig iron from other works could be discontinued after 1880. In the year of Alfred Krupp's death, the quantity of ore obtained by the factory from its own German mines was almost 500,000 tons and considering the extent of the as yet unworked mines, and the simultaneous development of the Orconera Company, he could go down to his grave with the certainty that he had secured a supply of ore and coal for the Cast Steel Works for many years to come.

The import of Spanish ore caused the Krupp firm to develop a service of steamers of their own, which was begun in 1873, when the first Krupp steamer was built by the North-German Shipbuilding company at Gaarden near Kiel, whence the Germaniawerft, now the property of the Krupp firm, originated. The two first boats were named the 'Essen' and the 'Sayn'; they each had a tonnage of 1700. Bigger boats were impossible owing to the unfavourable conditions of depth in Bilbao harbour. Neither of these old boats is plying now. In 1874 two steamers of the same tonnage, the 'Fried. Krupp' and the 'Orconera' were added, these were built in an English shipyard. After the port of Bilbao had been improved in the 'nineties, steamers of greater draft could be employed, and a fine new one of 3700 tons was built at Kiel in 1910. She received the name of 'Dr. Adolf Schmidt' in memory of the commercial director of the Cast Steel Works who had died in that year. The two older boats as well as this new one continued in use for bringing the Spanish ore to Rotterdam, until one of them, the 'Fried. Krupp' foundered with all her crew, the week before Christmas 1911, in the terrible gales that raged for some days in the Bay of Biscay, and in which unfortunately many ships were lost. The Krupp shipping business was managed for some few years by the firm's agents at Flushing; in 1877 the "Krupp forwarding and shipping Office" was established for this purpose at Rotterdam, and still manages all business concerning the Krupp steamers.

When Alfred Krupp bought the iron-ore concessions in 1864, that is to say before the purchase of the Saynerhütte, he was firmly resolved to make himself quite independent of outside iron works as regards the production of pig iron. Even if he had not succeeded in purchasing Sayn, which for some months seemed likely, Krupp would have turned his eye on some other iron works. As the working, both of the Sayn furnaces and of the Mülhofen works bought at the same time, was for reasons mentioned before, confined to the production of pig iron and raw steel for the puddling process, iron smelting was rather limited in spite of the continued acquisition of iron-stone mines, till the discovery of the Orconera ores in 1871 opened an inexhaustible supply for the production of his own non-phosphoric iron. The same year another small iron works, the Hermannshütte near Neuwied, with extensive property in mines in the Lahn district came into the possession of the Krupp firm. The situation of these new iron works was as little suitable as that of Sayn and Mülhofen for smelting foreign ores, so that when the Orconera Co. was founded, Krupp began to look round for efficient blast furnaces on a suitable site. For some time he hesitated between different plans of the most far-reaching kind. He would have preferred to put up blast furnaces of the largest dimensions in the immediate neighbourhood of the Cast Steel Works, so that the iron tapped there could be at once worked off in the converters of the Bessemer plant. The building of big blast furnaces in Spain was also taken into consideration, so that the ore could be smelted where it was obtained, and only pig iron imported thence. Finally both plans were rejected, and in their stead, in July 1872, the Johanneshütte on the Lower Rhine near Duisburg, rather extensive iron-works for that time, were bought from the German-Dutch Iron works Company, who had owned them since 1856. The Johanneshütte had at that time three blast furnaces working and a fourth building. By improving the hot blast apparatus and altering the design of the furnaces, the productive power was raised, the improvement of the furnaces on the Middle Rhine was also vigorously pursued. When the Mülhofener works had been taken over, there was one small, old fashioned furnace, three were now built for a daily output of 35 tons, while in the Hermannshütte, too, soon after the purchase, three large furnaces had been built. Until the Bilbao mines were quite completed, Krupp kept his blast furnaces going partly with his own ore, partly with what he bought in the south of Spain and Africa. From 1875 onwards the importation of Orconera ore gradually took the place of these other supplies, and now the Krupp smelting business assumed such dimensions, that the output, which from 1865 to 1871 had fluctuated between 10,000 and 20,000 tons, reached the height of 200,000 tons by 1880. The years of commercial depression and the repeal of the duties on iron, which bore so heavily on German industry and on Krupp in a general way, had no great influence on the production of pig iron, as these years exactly coincided with the increase of home production, and its substitution for imported English iron, which state of things lasted for some years. On the other hand the new Customs Tariff of 1879 showed its effect in a very grat increase of Krupp's production of pig iron. Another considerable advance took place in 1887, the year of Alfred Krupp's death, when the output of pig iron for the first time exceeded the demand of the works, so that large quantities could be put on sale. So in this department, too, Krupp could say at the end of his life that the aim of his unceasing efforts was attained, and that humanly speaking, the factory was independent for many years to come in the production of pig iron.

With the growing extent of the factory, and its development into a great combine, the internal organisation of the work and administration had also progressed. It gradually assumed a definite form in the 'sixties, but its beginnings date very much further back. Even at the beginning of the 'thirties we can notice a division of labour; while Alfred Krupp undertook the entire management, certain parts of the correspondence and matters of peculiar importance, his brother Hermann took the management of business, with the greater part of the correspondence; the engineer Speer, the first technical employee of the firm, the building and equipment of the workshops, Thies, the travelling, and Becker the book-keeping. Some of the workmen also, who had specially distinguished themselves, were placed in positions of trust in the shops. As the younger brother Friedrich became a man, and when Ascherfeld entered the business and Gantesweiler became head clerk, it was possible to make a still further division of departments, whereby the burden of detail, which had till now fallen on Alfred Krupp, was lightened, so that he could give his undivided attention to the general management. On Friedrich Krupp's leaving the business in 1849, Gantesweiler, whose worth he knew, was given the proxy, and the technical management was entrusted to Ascherfeld during Alfred Krupp's frequent journeys; Ascherfeld was addressed and respected as "Director" by those employed in the factory. In 1852, the office received a valuable addition by the appointment of Theodor Topp to the post of correspondent and cashier, he, by his faithful and wise management of business, won Alfred Krupp's confidence in such a degree that after Gantesweiler's death in 1856 he was given the proxy. Topp, who also possessed the unlimited confidence of Sölling, took his full share in the serious business anxieties of these years, and it is mainly owing to his calm and cautious conduct, added to Sölling's active help, that Krupp was able to stand successfully against the severe shocks of 1856/58. In 1858, when Topp's death in the prime of life deprived the factory of his valuable services, Krupp let the "Procura" which had existed since 1849, remain for years in abeyance, and only in 1862 appointed a collective procura consisting at first of only two members, which was enlarged as its duties increased, and which henceforth had to be responsible to the owner of the firm for the business management.

Meantime the technical organisation as well as the commercial, had followed its natural course of development. The duties of chief manager, which Alfred Krupp still reserved for himself in conjunction with Ascherfeld, were lightened in a measure, during the 'forties, by appointing a small number of foremen, chosen from among those of tried capacity, the oldest of whom used to work with the men under them until they retired altogether. It only became the custom gradually for the foremen to restrict themselves to supervision, and in 1851, Hagewiesche, who had greatly distinguished himself at the London International Exhibition, was the first to be appointed to a post of head manager of all the workshops. Alfred Krupp used to call him in joke "the foreman of all the foremen"; his great mechanical abilities indeed enabled him to plan all kinds of improvements in the machinery, and to overcome all hitches in working. Krupp had a very high esteem for such men as showed themselves capable of thinking for themselves, and using their ideas in the interest of the factory. Pelz and Ruhland, the first managers of the forge and tyre-rolling mill were such "deep thinkers" and belonged to the number of those who enjoyed their master's confidence. As time went on, some engineers were engaged who had not emerged directly from the ranks of the workmen. Krupp brought most of these back from his journeys, from well-known Berlin engineering works. In this way the modest draughting office at the Cast Steel Works was started. It began in 1852, in two small rooms forming part of the dwelling house, which were also used as the office. Then more roomy offices were built adjoining the new forge, and the designing office was placed in the upper floor of this building. The working out of all plans for enlargements, for mechanical equipment, as well as drawings for orders that came in, fell to the share of this office, which till 1856 only possessed four draughtsmen, and was presided over by the engineer Gustav Diechmann. The real head was however the dominating personality of Alfred Krupp, whose power of incessant work spurred on all those who worked with him. Certainly there was no question then of working out drawings for new plant as they are worked out now; Krupp himself supplied almost all the rough draughts and left the carrying out of details to the draughting office. When the great enlargements were made in the factory and plant during the 'sixties and 'seventies, the work of the draughting office increased considerably, but even in 1873, when business was at its height, there were only 16 employed in it. In fact the organisation of the office has only assumed greater proportions with the recent extensions, the perfecting of all the technical appliances, of the metallurgical processes, of the mechanical shops, of the means of transport, &c. It has remained also in later times the central office for the working out in detail of plans for all the new buildings and alterations in the factory and the outlying works, but the formation of a number of subordinate departments has lightened its work; there are now ten of these. Among the biggest erections planned recently in the draughting office are the armour-plate rolling shop with its gigantic hydraulic presses, the new mechanical workshops, the plant of the Friedrich-Alfred-Hütte, and the almost entire rebuilding of the Germaniawerft.

Krupp always had the new buildings in the Cast Steel Works carried out under his own management, and as far as possible by his own workmen, at first by Essen carpentering and building foremen, after the end of the 'fifties by his own building office which was first managed by the foremen-carpenter Barchewitz who built the "Garden House". At that time no great value was put on detailed plans or drawings in building workshops. An old upper foreman drastically describes the setting about of new buildings during the 'fifties; "When mechanical shop II was laid out, Krupp made a certain number of paces, and then turned round, and if the length thus measured did not seem enough, made a few more, then he said:—'All right, just begin digging here.' He didn't take long to plan a building." Other men employed at that time give similar accounts:—"There was no architect then-a-days. Herr Krupp was his own clerk of the works, when he wanted something done, he sent for the foreman-carpenter Grunewald, drew a few lines on the ground and thus showed him exactly what was to be done." Many sketches, moreover, made by Krupp, show how carefully he attended to details as well, and how thoroughly he understood them. The chief points with him were to secure durability by good building and to keep every erection in thorough repair. During the period of rapid development in the 'sixties, the Building Office also grew more quickly and several departments connected with it, originated, they were collectively placed under the management of the Government Architect Kraemer in 1863. The first building shops with mechanical plant were put up near the small proving ground of those days; in 1871 they were once more enlarged and together with the Building Office removed to Westendstrasse, where the erection of a saw mill followed. During the 'seventies a second temporary Building Office was added under special management, to meet the great demand for work caused by the erection of workmen's dwellings, colonies, lodging houses, supply stores, &c.

With the institution of the commercial office, the draughting and building offices, and of the so-called administration of stores, which had charge of the carting, railway, day labourers, raw materials, coke ovens, brick yards, bakery and lodging houses, great progress had been made in the division of the work of administration. The separation of the steel works and forges into separate departments on the one hand, and of the mechanical and gun shops, which were now rapidly increasing, on the other, next followed in the 'sixties. Afterwards the shops were divided systematically into departments according to their work, and placed under special clearly defined management. As early as 1865, the factory was divided into twenty groups, each under its own manager; besides those already mentioned, the most important were:—the forges, the tyre-rolling and the rail-rolling mills, the Bessemer plant, the puddling shop, the boiler forge, the spring shop, the iron foundry, the testing house and the laboratory. These departments were again grouped according to technical principles into larger departments placed collectively under a single management. In 1870, the manufacturing shops were divided into eight departments, the first comprised chiefly the crucible-steel foundry, the open-hearth steel shop, and the forges; the second, the Bessemer plant, the puddling and rolling shops; the third, the gun shops, and the fourth, the other mechanical shops. The remaining departments comprised the building office, stores and other auxiliary departments. In 1873 the number of departments had risen to nine, in 1878 to ten. The organisation of the commercial management improved too. A number of separate offices were formed from the head office for disposing of commercial and administrative matters; to these an auditing office was finally added, which had the supervision of the whole undertaking; a kind of upper chamber of accounts, though it was subordinate to the Procura, to which the supervision of all the cashiers and accounts was entrusted. In 1872 when the old office building had become too small for its work, a special administration building was erected; it has been enlarged several times, and has remained till 1911 the seat of the central management and of the Procura, or as it was re-named later, the "Directorium".

These organisatory measures were rounded off and strengthened by the so-called "General Rules and Regulations" of 1872, made for "the working and administration of all establishments, mines, other building property and business of the firm of Fried. Krupp". Alfred Krupp had been working seriously at these Regulations for years, urged by his own failing health, and the ever-increasing extent of his enterprise. They still contain, mostly in the original words, the fundamental rules for the entire organisation of the factory. A few changes have been made in the course of time, which tended to modify some rather too detailed stipulations as to the collaboration of the members of the Procura, and to adapt them to the progress of the concern. The prefatory words written to justify the setting up of the Regulations say:—"the growing extent of the factory makes it appear both desirable and necessary to collate and complete those principles and rights through the exercise of which the present prosperity of the firm has been obtained, and at the same time to specify and define the rights and duties of every appointment and every position in the works, and in the management, so as to guarantee as far as possible for the present, and for future days, an established order and an harmonious co-operation, and thereby to secure the progress of the whole and the well-being of each member of the community." The first part contains a number of valuable rules for the conduct of business and the management of the works, then comes a definition of the rights and duties of those employed, and lastly an extensive programme for the continuation of the institutions for the welfare of the workpeople, a programme which is still the basis of what is done in this direction at the present time. Then follows a paragraph relating to the Procura, by which the supreme administration of the entire business of the firm is to be conducted. The Procura so represents the head of the firm, that all decisions made by it are considered as proceeding directly from the head of the firm. It takes its directions only from him and is responsible to him that business is carried on in the spirit in which he desires the firm to act. The Procura undertakes the whole of the outside business, dividing it among its various members. The division of the Procura into departments must not influence its unity of management, on the contrary, the unanimity of the members of the collective Procura is required as a matter of course in all measures and decisions which are at all important. To this end mutual consultations and discussions are to be the rule for the settlement of business matters. Notwithstanding the modifications that have naturally resulted from the great increase of business this collegiate system is retained in so far, that the responsibility for the general state of business still rests with the collective Procura. The next paragraphs of the General Regulations relate to the departments and shops. All the firms' shops and establishments are divided into departments; that is, groups of producing and administrating branches. Every department has its own chief manager. His duty is to have an eye everywhere, to investigate, to encourage, to watch over the management of business and the work done, to keep in order that which already exists, to provide and develope improvements, and finally, to insist on the effective maintenance of discipline. For this purpose the manager of a department must be very careful not to fritter his energy away in attending to mere details, but rather keep an observant eye on the whole and its management. The business done by one department with another and with the Procura is as a rule transacted by the chief of the department; he keeps the Procura constantly informed of the state of his department, and consults the Procura about the transaction of current business. He has to help to choose the head engineers and foremen. The departments are subdivided into various administrative or producing branches or shops. At the head of each of these there is a head clerk or a manager responsible to the chief of the department. His duty is to manage the shop or office in the manner prescribed by the precept and practice of the firm, and the direction of the chief of the department. The head of the shop has to give the head of the department a regular report of the work done, and of every occurrence of any importance. Subject to the approval of the head of the department he appoints the foremen, overseers and clerks required in his branch. He engages the workmen, but the head of the department fixes the wages and other points of the contract. The head of the shop can also dismiss men. Foremen and overseers can neither engage nor dismiss men on their own account. The questions which arise in the ordinary course of business must be decided by the head of the shop alone, the chief of the department must only be applied to, when extensive experiments or alterations in the equipment of the shops or in the process of manufacture are proposed, and according to circumstances the decision must be referred to a meeting of the Procura. The head of the shop has to see that no raw produce or manufactured articles are brought into the shop or taken out of it without being thoroughly tested and examined as to their condition. The whole personnel of the workshop, foremen and workmen, owe implicit obedience to the head. The chief of the department must avoid undermining the authority of the head of the shop by direct interference with the work. But he must be none the less thoroughly convinced that every man is doing the duty allotted to him, so that mistakes and disorder may be avoided and no abuses may be suffered to creep in.

The General Rules and Regulations also contain a number of fundamental rules for a system of agents to represent the firm, which are still in force. The firm had already a great number of agents both in Germany and abroad when the General Regulations were issued. The beginnings of these agencies, especially those in France and England, were spoken of in connexion with the development of the factory during the 'forties and 'fifties. We have only now to speak of the further extension of the system. In 1855 the Paris agency was, after various changes, at last put into the hands of Krupp's traveller H. Haass, who had proved his worth by long years of service in the firm. Haass also took over Krupp's interests in French Switzerland and in Spain and Italy, and he was authorised to sign for the firm; he represented the firm with success until his death in 1880. Since that time the French business, which had decreased greatly in comparison with what it had been, was done by agencies. In England, after many unsuccessful attempts to find a London firm which would represent his interests, Krupp at last, at the beginning of the 'sixties, found the right man in the person of the still youthful engineer Alfred Longsdon. A close friendship was soon established between the two young men, which was accompanied by excellent results for the English connexions of the Cast Steel Works. In 1856, Longsdon entered the service of the works entirely and managed the London agency. After 1864, he was made a member of the Procura and had the right of signing for the London branch of the firm, as Haass had had for the French. Longsdon worked vigorously and with success at the introduction of Krupp railway material into England and the English colonies. In 1860 the agency for the East Indies was entrusted to him. Later on, too, Alfred Krupp allowed him an influential voice in the technical management at Essen. His opinion and advice were asked on many metallurgical matters. In 1873 he was appointed a member of the Procura at Essen, but he still continued to represent the firm in England, and it was not till his death in 1893, that the London Branch and Procura ceased to exist. Alfred Longsdon was one of the little circle of intimates who enjoyed Alfred Krupp's unaltered friendship till his death.—As early as 1851, the firm of Prosser & Son represented Krupp in New York. Rolls, tool steel and railway axles were the first articles sold in the United States. After the invention of the weldless tyre, the American business quickly assumed great importance, and has remained very brisk until the present day. The Prosser family, like most of the Krupp agents of old times, are on terms of personal friendship with the owners of the Cast Steel Works, as well as on a business footing; the agency in the United States is now in the third generation of the Prosser family.—Among the European agencies, those of Russia and Austria must be mentioned as particularly old and successful. But in Russia, too, it was long before Alfred Krupp found a man who would devote himself to the sale of Krupp productions with the requisite energy. Not till the St. Petersburg agency was undertaken by C. Barth in 1859, did the business done there, principally in rails and war material, begin really to thrive. After 1874, the Russian agency was given to Wachter & Co. in whose hands it still remains. The Austrian agencies first became important through the efforts of M. Ficzek of Vienna, an extremely capable representative, who was appointed when the first weldless tyres were introduced there. Ficzek, who was also the agent for the Rothschild Bank, and who was on the best of terms with the Austrian State railways and private lines, did a great deal towards introducing Krupp manufactures into Austria. He managed so well that every locomotive and every tender in the land were provided exclusively with cast-steel tyres, and his death in 1862 was a heavy loss to Alfred Krupp.—None of the Krupp agents in the German states has had such success as C. Meyer, who began by travelling for the firm in 1854, and afterwards became the Berlin agent. Meyer, who is equally remarkable for his business capacity and his personal character, has by means of his travellers and sub-agents, organised an agency for Krupp manufactures in most of the Federated States. He proved so capable an intermediary in dealing with customers, with banks and with government officials, that Alfred Krupp frequently entrusted him with the most delicate transactions. Meyer also had a considerable share in the weighty conferences with the military authorities, with Bismarck and other members of the government. After he had been appointed to the Procura a great deal of his business was handed over to agents in the immediate service of the firm. In 1881 his health, which was much shattered, compelled him to resign his seat in the Procura of the Cast Steel Works.

The present system of representation is, on the whole, still organised by the rules laid down in the General Regulations, which divide the agents into three classes. The first class works exclusively for the firm and its interests. Such agents are not allowed to take up any other agencies. The second class may, under certain conditions, hold other agencies as well; but they must not come into collision with the interests of the Krupp firm. Then there are sub-agents to work certain countries, towns, or districts divided off from the larger district. Rules are laid down for the conduct of business for all these classes of agents, fixing every detail of their duty, and which serve at the same time to bring the work of the agents into harmony with the general tendency and principles of the firm.

If, however, the organisation of the works kept pace with their extension, we can by no means say the same of the finances. When Alfred Krupp took over the works in 1848, they were really poverty-stricken, there was no working capital, and absolutely no funds to put up new plant. The old difficulty of raising money recurred every time the works had to be extended. It is true that Alfred Krupp always kept to the principle of reinvesting all the profits in the factory, but very often the returns barely sufficed to provide the necessary working expenses, not to speak of the means for building new plant. This is not only true of the 'fifties, when the profits were very small, but it was also the case later on, when first the manufacture of tyres and then of guns brought in bigger returns. A glance at the maps, and a comparison of the size of the Cast Steel Works in 1848 with that in 1873, makes this quite clear. Krupp's chief support in the hard times of the 'fifties, was Sölling, the most faithful of friends. He, the cautious business man, did not always agree with Krupp's eagerness to advance, and there were often serious discussions between the friends, whose characters differed greatly. "The news that you are going to order a steam hammer terrifies me, where is the money for it to come from? Festina lente, which means, 'most haste, less speed'. He who flies, before his wings are grown, comes to the earth with a bang and lies there," says Sölling in a letter written in 1852, and again he writes:—"I have the greatest confidence in all your creations, I only beseech you not to forget the financier in the manufacturer, the one cannot do without the other", and "You imagine that the credit of the firm is as good as its reputation; but that is not the case, and for this simple reason that from time to time we ruin it by overstrain." But, however often Sölling complained that Krupp presumed too much on their friendship, still he never wearied of giving help, either by placing capital at Krupp's disposal, or by taking a guarantee for his credit, or by using his influence in some other way to benefit the business. Still his financial help alone was not sufficient, and other means had always to be sought. There was even a proposal made to turn the factory into a limited company. It was Sölling who suggested this resource several times, alluding to the precariousness of the situation. He wrote in 1853:—"I put it to you for consideration, if it does not seem advisable to make over our whole plant and premises to a company on the most favourable terms we can get. If considerable supplies do not soon come in, I really do not see how we can pull through." Such founding of companies, which were formerly very rare in Germany, frequently occurred at the beginning of the 'fifties, in the iron industry especially, many old enterprises were taking this form. Thus the Hörder works were turned into a limited company in 1852, the Bochum works in 1854, the Stettin Vulcan in 1857. From a financial point of view, it would have been the best way possible in those days to put the future of the factory on a broader basis, and to facilitate the procuring of further pecuniary resources for subsequent extensions. But Alfred Krupp would not hear of such a measure, and also refused to mortgage the whole concern. He desired to remain independent. So this weak state of finance prevailed for some time longer. The time from 1848 to 1856 was really the most serious in all the history of the Cast Steel Works, especially as the banks would only grant credit to a concern in so uncertain a state, on security either of mortgage or guarantee. But in 1853 Krupp succeeded in getting fresh partners, who brought rather large sums into the business. This was indeed help in need, for the financial position was once again very bad. The first of these deeds of partnership was drawn up in March 1856, with F. L. Niemann, of Horst near Steele, who had been doing business with the Cast Steel Works for some time. Niemann was made a sleeping partner with a share of the profits; the value of the Cast Steel Works was put at 2 million Talers, and the lowest return on the money put in was to be 7½ per cent. The contract was made for five years, but was not renewed, on the contrary, the sum invested by Niemann was converted into a loan, at a fixed rate of interest, which existed for ten years longer, and was paid off in 1872/73. In March 1857 a similar contract was made with the brothers Ernst and Julius Waldthausen, the heads of the banking firm Wilhelm & Conrad Waldthausen at Essen. They also became sleeping partners in the Krupp firm on the same terms as Niemann. Krupp was also to have the right of getting advice from Waldthausen Brothers on special terms of remuneration. The latter had the right of giving notice directly they were "dissatisfied with the way in which business was conducted". The contract ran till the end of 1861, in case of non-renewal the money invested was to be returned within a year. Ernst Waldthausen, who was about the same age as Alfred Krupp, and had been his friend from boyhood, had already looked into the finances of the Krupp business during the absence of his friend in 1856. He was not satisfied with the way things had been managed hitherto, and when the contract was signed, he said "he would introduce a different system into the financial department". But Krupp resented such interference with "friendly candour" he wrote, he was not going "to allow any one to settle things here", and "I love my friend Ernst Waldthausen for his disposition and esteem him for his good qualities, but as he is too apt to try and take the lead, whenever he is working with others, I think it better not to let this occasion pass without speaking my mind once for all. As I have said, I shall ask for advice, when I want it."

The new partners invested a sum of nearly $^1/_4$ million Talers in the business. So the greatest difficulties vanished for a time. Such help was all the more valuable because in 1859 Sölling died. This was a serious blow to Alfred Krupp, who not only lost a friend, who was always ready to help with advice and deeds, but he had also to consider, how he could repay to the heirs the money Sölling had lent him. As the fairly good profits which were coming in were all being swallowed up in enlargements of the works, the sum could only be paid off by raising loans from friends and relatives. From the beginning of the 'sixties, Krupp's friend of many years' standing, Gustav Jürst, and after 1862 Hermann Krupp too, placed considerable sums at Alfred Krupp's disposal in the form of loans which proved a welcome help during the time the works were being enlarged. At the beginning of the 'seventies these loans were mostly paid off. Thus it was possible to pay off the Waldthausen capital quickly in 1862, at which time Niemann's was converted into a loan. After this Alfred Krupp took no one else into partnership.

Banking connexions played an important part in Krupp's financial affairs at that time. The first of these connexions began in 1834, with the banking firm Herstatt of Cologne; by means of this, Krupp's business with South Germany—at that time rather brisk—was much facilitated. Until 1848 Herstatt was the only banker of the Cast Steel Works. He granted a credit up to 8000 Talers, which was raised to 15,000 in 1842, when the non-payment of large sums from Austria had placed Krupp in a very critical position. At that time a mortgage to the amount was laid on the works, as a guarantee for Krupp's credit, which he sometimes considerably overdrew. In 1849 Krupp began to do business with the Cologne banking firm Salomon Oppenheim & Co. The credit granted him here was guaranteed by Sölling. The correspondence with this firm soon assumed a rather unpleasant tone; for every time Krupp overdrew his account—which he was often compelled to do—he was at once sharply admonished. This is quite comprehensible when one remembers both the general state of commercial security and the as yet not well-established reputation of the Krupp firm at the time, but it certainly helped to give Alfred Krupp a personal feeling against banks in general, which made the business he was obliged to do with them more difficult, even in later years. Once Oppenheim demanded an immediate settlement of accounts and threatened "serious measures". The matter was only adjusted by Sölling's giving a further guarantee. One of the partners of the Oppenheim firm was chairman of the administration board of the Cologne-Minden Railway Co., which was a matter of great importance to Krupp at that time. So the connexion was kept up with this bank even later on. In 1853 Krupp began to do business with the Schaaffhausen Banking Co. of Cologne, who also gave him credit on guarantee. Meanwhile the firm was coming to terms with Berlin banks; first with the Disconto Co., afterwards with Mendelssohn & Co., Bleichröder and Warschauer. On the whole the bankers did not speak well of Krupp, as he was not particular as to overdrawing his account, and could at times behave rather inconsiderately. In 1856 a banker writes to Ernst Waldthausen:—"However high I place Krupp's genius as a manufacturer, I have at present little reason to admire him as a financier." To which the other replied:—"Your opinion is shared not only by So-and-So—but by all those in the financial world who have to do business with him." In 1858 Krupp entered into connexion with the newly-established banking firm Deichmann & Co. of Cologne. The connexion was based on the close personal friendship of the heads of the two firms, and turned out very well for the Cast Steel Works. Deichmann granted Krupp such liberal terms, and the financial situation for the time was so favourable, that he was able to decline proposals to open accounts with two banks which Deichmann introduced to his notice. When the war of 1870 broke out, Krupp, on his side, was able to render the friendly banking house valuable services, so that the connexion became even more confidential. When the enlargements of the factory were planned in 1871, Deichmann offered the firm unlimited credit. "The larger the sums you draw on us, the better we shall be pleased." Finally we must mention the banking firm Paul von Stetten of Augsburg which did a great deal of business with the Cast Steel Works, in consequence of the sale of railway material to South Germany. Krupp's Paris banker was F. A. Seillière, who made him a big loan of 4 million Francs in 1865. This was paid back in 1869.

With Krupp's growing success his credit rose, though, owing to the continual extension of the works, the state of the finances themselves did not become much better. For instance, in the great increase of trade which followed on the war of 1870/71, there was no difficulty for the time in procuring sums large enough even for the enormous extensions of the Essen works and the outlying ones. The firm's credit seemed now inexhaustible and its obligations and liabilities reached an almost dizzy height, which, at a sudden change in the state of trade, could not but become perilous. The ease with which money could be raised, combined with the general state of affairs in that company-founding era, partly explains why Alfred Krupp did not set to work to put the future of the firm on a secure footing in this matter too, and to procure a sufficient and completely sound basis for the finances of the factory, by some great financial operation, by raising a loan which could be paid off slowly. Such a measure was urgently demanded at the time, and though it could hardly have been effected till well into the 'sixties, still when the financial position was so favourable there could have been no great difficulty in the matter. The neglect of such a measure can be traced to personal grounds. Sölling, who had always shown so true an instinct in foreseeing a crisis, who had so often warned Krupp against straining his credit without, at the same time, safe-guarding the factory, Sölling was no longer there to give wise counsel. Once he had written:—"I would not give So-and-So such power over me for any price whatever." But there was no one now who had sufficient influence over Alfred Krupp, and he himself—more an industrialist than a financier—never became really conscious of the perils to his ever-growing factory, which arose out of its financial situation. So all the money he wanted—so far as the returns of the factory did not supply it, and that was but a small proportion—he continued to raise on credit without hesitation. That was a mistake which brought bitter punishment, when in 1874 a serious crisis gathered over German industrial life.

## INSTITUTIONS FOR THE WELFARE OF THE WORKMEN.

The rapid growth of the Cast Steel Works was accompanied by the development of a system of institutions for the welfare of those employed, a system which has been fiercely attacked and warmly defended. These institutions, which began with the Sick-aid and Pension Funds, date from the 'fifties, a time when comprehensive measures of this kind were unknown, except in the mining industry. They originated solely from Alfred Krupp's generous heart and his warm sympathy for the troubles and needs of people of small means, to whose number he himself had belonged for so many years. They sprang also from his generous appreciation of the work of those, who had placed their confidence in him as an employer; he fully recognised that an employer's responsibilities do not cease with the literal fulfilment of the contract between master and men, and his efforts for their well-being are based on a broad-minded conception of the position and duties of an employer, who as a member of the whole, feels himself called upon to provide for the good of the whole; a conception which Alfred Krupp expressed in the words:—"The end and aim of labour is the good of all, such work brings a blessing, such work is worship." He insisted on the idea of a permanent bond in mutual work "for better and for worse", a bond, whose head should provide security and succour for every member of it. He shunned no sacrifice in the attainment of this object; he burdened himself with the Sick Fund and the Pension Fund at a time when the means at his disposal were comparatively small, and when he built 2500 workmen's dwellings (1871—1874) he stretched his credit with the bank to the utmost.

The seeds of the principles which guided him in these matters had been sown long years before, by his parents. We know that Friedrich Krupp was ever the ready and willing helper of his men in poverty and sickness. The loyalty of the men rewarded him, and when the breach with Nicolai came they all stood by him. Friedrich's widow, too, when she assumed the management of the works, took thought for the wellbeing of those who had served her late husband faithfully. In a letter to the Mint Official Kleinstüber she writes; that, if the undertaking can be kept going, it will provide work and wages for a number of able and loyal workmen. Alfred Krupp was thus early grounded in such principles, and they strengthened through the long years, when, in the little factory, master and men, working side by side, formed that bond of mutual dependence, which Alfred Krupp valued so highly, while the workmen, on their side, realised that their master was one of themselves, sharing equally in their cares and anxieties. His chief desire was to help the poorest of the workmen, those whose wages were lowest; this principle prevailed in all the provisions he made for their welfare. In an address to his workmen, issued in 1873, a picture of his early home accompanied his remarks on the poverty and anxiety from which the works had once suffered, and the subsequent success with which the family home had subsequently been blessed, and he added the hope that this consideration might increase the respect for small beginnings, the sympathy with their attendant cares. A letter written by Alfred Krupp to his physician, whom he wished to convince of the importance of his task of keeping 50 men fully occupied, referred to above, in 1834, shows how completely he accepted his responsibility for the lot of his men.

It is, truly, an interesting study to follow out the ideas and considerations which influenced Alfred Krupp in creating and developing his institutions for the welfare of his men. He started with the maxim that his men's wages must be as high as possible. "Our workmen," he said, "shall receive the maximum that industry can afford." He further considered it right that employment should be found for all steady workmen, even when business was slack, and that if possible, none such should be dismissed. When his "Procura" once recommended a reduction in the number of hands, he answered:—"There is no hurry; we have no shareholders waiting for dividends." In 1848, when things were going very badly at the Cast Steel Works, he had the last bit of family plate melted down to pay the men whom he did not want to turn off. He had every right to say, in 1872:—

> "Forty-five years ago, I stood among the ruins of the works which I had inherited "from my father. My few workmen were ranged alongside of me. The daily wage for "smiths and founders was then raised from 18 Stivers to 7½ Silbergroschen, the whole "weekly wage amounted to 1 Taler 15 Silbergroschen. For fifteen long years I made "just enough to pay the men; in return for my own work and anxiety I only had the proud "sense of having done my duty. As times improved, and as the works grew and throve, "I gradually raised the wages; as a rule, I anticipated all demands, and this rule shall "still remain in force. When industry was paralysed by lack of means of transport, "when no orders came in, I still found work for my men, and no loyal worker has ever "been turned off. There are still many of the old workmen who can bear witness to "this. Ask them what was done for the workmen in 1848. The sacrifices made later "during the war are well known to all."

This, however, did not satisfy his sense of the duty he owed his men. His practical mind early recognised that by good wages alone he would never compass his great aim of establishing and promoting the welfare of all belonging to the works. The experience of the 'sixties and 'seventies confirmed him in this opinion. During that time there was a general rise of wages, as a result of the growth of industry. The average daily wage at the Krupp works was, in 1865, M. 2·37; in 1870, M. 3·08; and in 1874, M. 3·86. But the men had not become more contented for all that. If wages had risen, so had the price of all the necessaries of life, especially of food and housing. Alfred Krupp wrote at the time:—"The men have never earned so much as they do now; it is not low wages which are causing discontent, but the diminished purchasing power of money, especially as regards rent and victuals." The consequence was, that Alfred Krupp resolved to continue in the path he had already entered upon, and to remedy the evil by a comprehensive system of institutions for the welfare of the workmen. He built dwellings for married workmen and let them under costprice; he put up lodging- and eating houses for the unmarried; he established Supply Stores, where good and cheap wares, especially the articles necessary for daily life, could be bought.

Krupp considered the importance of these institutions for "social betterment" of all engaged in the works mainly to lie in their being a supplement to the wages. A workman's earnings are determined by many factors, besides his actual needs. The total of work done decides the lump wage for a whole category, regardless of other circumstances, whereas the special needs of each individual workman vary widely, perhaps permanently, owing to his numerous family; or temporarily, owing to special causes. Wages, as a rule, cannot be suited to these variations, and therefore the aim and end of Alfred Krupp was, to remedy and compensate for this, by making hisprovisions especially fitted for the necessitous. This extremely important function of such institutions, which is still hardly widely enough recognised or appreciated, may be clearly shown in Alfred Krupp's creations. The workmen's dwellings, which number over 6000 now, are let in the first place to the older workmen. As the rent is barely three-fifths of the usual local price, these dwellings actually represent a premium on old age. Besides tenants with large families enjoy immunity from the danger of being turned out, when, in times of great prosperity, dwellings are greatly in demand and rents rise. Again, as the Supply Stores do not work for profits, they can sell their goods cheap; the surplus profits are divided among the purchasers every year, in the form of discount on purchases; therefore the larger the family, the greater the advantage, first in buying and afterwards in the amount of discount. The prices, too, are fixed so that the actual necessaries of life, *i. e.* bread, meat, butter, lard, dried vegetables, coal, &c. are comparatively cheaper than less indispensable articles. This regulation of prices renders it easier for the workmen with large families to live upon their wages. The Imperial Insurance Act has taken but little from the value and importance of the Krupp Pension Fund or the Sick-aid Fund (which latter includes a hospital, convalescent homes, &c.) as supplements to the wages. The Pension Fund adds high pensions to those granted by the state, not only for men, but also for widows and orphans. For needy cases, when the age fixed for the pensions has not been reached, there are special provisions, which give aid either in one payment, or in continued payments.

Thus a system has been gradually built up, which, in conjunction with the regular earnings, is calculated to promote the welfare of all those employed in the works, according to their several individual needs. At first, these provisions were limited to those actually employed in the works, as was natural; for the primary object was to obviate the economic difficulties arising from the rapid development of the works during the 'sixties. But Alfred Krupp aimed at more than this, as is shown in the scheme laid down in the General Rules and Regulations of 1872; a scheme which indicated the way to his successors, and which was so comprehensive that, in spite of continual progress, it has not yet been fully carried out. Paragraph 19 of these regulations, which lays down the general principles, says:— The firm is by no means satisfied with the fulfilment of its merely legal obligations as a contracting party; its aim is now, as always, to provide special benefits for faithful service, and it will always show honour to those who have honestly devoted their strength and labour to the works. In paragraphs 20 to 23 we read:—In order to help its workmen and its staff the firm will continue to build dwellings for families, stores for the sale of food and clothing, lodging houses, savings banks, and other institutions of the kind. Special attention will be given to the providing of schools for the training and teaching of children and for the further instruction of adults, and for their amusement. By establishing Sick-aid Funds, Relief and Pension Funds, hospitals and kindergartens the firm will, as far as possible, protect the whole body of workers and their wives and children from distress in sickness, disablement and old age; the firm will also help to bear the burdens entailed by the fulfilment of military service. At the same time every member of the works is urgently recommended to insure his life. The firm will always be ready to mediate, in the effecting of such insurances on the most favourable terms.

It must be mentioned that perfect freedom of action is allowed in the use of these beneficent institutions, with two exceptions, namely, the Pension Fund and the Sick-aid Fund, contribution to which is obligatory. Contribution to the Pension Fund was at first not compulsory, but this, from obvious reasons, stood in the way of its permanent success. If the Pension Fund were to become a corporation enjoying the right of giving, not only temporary aid, but also of paying annuities of large fixed sums, the participation of all the workmen was required, and was therefore made compulsory. As regards all the other beneficent institutions, the men have perfect freedom to make use of them or not, as they choose. This liberty of choice also extends to such institutions as evening schools, libraries. clubs, and convalescent homes.

Scarcely anything can be added to the scheme laid down by Alfred Krupp forty years ago. His successors adopted it willingly, and have always considered it a precious heritage, Friedrich Alfred Krupp, standing besides his father's monument at the entrance of the works, declared, that "he, too, would requite loyalty by loyalty". Mrs. Margarethe Krupp, his widow, and Bertha, his daughter with her husband Gustav von Bohlen and Halbach, in 1906, ratified his pledge that the maintenance of a close bond with the employees, and care for their welfare would always be the object of their earnest endeavours. Later chapters will relate the comprehensive manner in which Alfred Krupp's successors have extended his institutions. Here we shall confine ourselves to the details of his own creations.

The first of these creations for promoting the welfare of those employed at the Cast Steel Works aimed at neutralising the loss and damage occasioned by illness, old age and death. A Sick-aid Fund existed at the works as early as 1836, a time when public attention was little given to such matters. Membership was optional; the weekly contribution was, at first, 1 Silbergroschen, and all fines were paid into the fund. The firm seems to have paid for medicine and medical attendance. Between 1845 and 1847 a regular doctor was engaged. The aid given was calculated according to the amount of a man's wage; till 1841, 5 Silbergroschen, later 7½, were paid daily for every work day, which was a considerable amount for those times. Relief was also given to needy workmen and to widows, when the state of the fund allowed. The management was in the hands of a committee of workmen. The number of members paying into the fund varied from 58 to 90 per cent. But this arrangement proved insufficient, when, at the beginning of the 'fifties, the number of workmen greatly increased, and in 1853, the Sick-aid and Burial Funds of the Cast Steel Works were established on broader lines, out of which the institutions now in force have gradually developed. The firm gave a donation of 100 Talers, and pledged itself to a yearly contribution of that amount, on condition that so useful an institution should be managed as conscientiously as it deserved by those elected into the committee. The contribution of members was raised to 3 Silbergroschen a fortnight. Any surplus was to be given to disabled workmen. Membership remained voluntary with the result, that in 1855, out of 700 workmen there were only 200 members. Obviously the Sick-aid Fund could not thrive under those circumstances, and Alfred Krupp resolved to alter the system. By the new statutes of 1855, membership was made compulsory for all belonging to the works. The subscription was raised and regulated according to the amount of earnings, the same changes were made in the amounts paid out in cases of sickness and death. Those earning daily 25 Silbergroschen, and upwards, formed the highest or fourth class; this class subscribed 8 Silbergroschen a fortnight. The daily relief in sickness was fixed at 12 Silbergroschen, when the sick man was nursed at home, at 3 when he went to the infirmary, burial money for the fourth class was fixed at 15 Talers. The year 1858 saw an important change in the constitution of the Sick-aid Fund, by the establishment of the proportion between the firm's subscription and the members' payments. The former bound itself to pay 50 per cent of the members' subscription, it became chairman of the managing committee, and possessed one third of the votes at general meetings. Two other classes of wage-earners were established:—*i. e.* those receiving permanent wages of 30 and 35 Silbergroschen. The institution received legal recognition. These changes of 1858 gave a more definite form and a firmer foundation to the Sick-aid Fund and secured its prosperity for the future. The Krupp relief funds of that time correspond in all essential details, such as, compulsory membership, statutes and benefits, to the Insurance Act which became law 30 years later.

Alfred Krupp once explained the object of his Sick-aid and Burial Funds in the following words:—"The establishment of them gave me great pleasure and satisfaction——My original intention was to provide reliable and inexpensive help in times of sickness; if a man was engaged one day and was disabled on the morrow, not from constitutional delicacy or his own carelessness, but by an accident occurring to him while at work, the works should held responsible; or when a man has devoted his strength and unflagging efforts for long years to me, as Vierhaus, Schürmann and others have done, he should be enabled to spend his declining years without working or starving——." In course of time the objects of the institution were still further extended and developed. A married man received relief during illness for each child under fifteen; a man disabled by accident received extra sick pay, so that he got altogether two-thirds of his regular earnings. A fund for a family doctor was also established, to provide medical attendance gratis for the wives and children of its members.

Since 1885, the Sick-aid Fund at the Cast Steel Works has been subject to the regulations of the Insurance Act. For a time the extra payments were made out of a special fund for relief in sickness, but this was incorporated with the Sick-aid Fund in 1904. The fund claims 4½ per cent of all wages not exceeding 5 Marks a day. It offers far greater advantages than those determined by the law. It grants medical attendance and medicine from the first day of illness; in cases ot total disablement the sick money is 60 per cent of the earnings, and in the latter cases the additional relief for children is as much as 15 per cent. The relief is granted for 26 weeks. Six months' membership entitles a member to aid in sickness for 39 weeks, if there is any hope of his finally being able to resume any kind of work; after 39 weeks, he has free medical attendance and medicine till the end of the 52nd week. The committee also have the power of giving additional aid to disabled workmen who require to go to a sanatorium. A member's wife and children have medical attendance free of charge from the club doctor in illness or in confinements. Burial money is paid, on the death of members, to the members' wives and children. The burial money amounts to thirty times the wage which decides the sick pay, burial money for the wife is two-thirds of that sum, for children, it varies, according to their age, from 10 to 35 Marks. To complete the work of the Sick-aid Fund special endowments exist, which are at the disposal of the committee in cases of special need, for instance, relief can be given in the form of ready money in cases of sickness lasting six weeks or longer.

Of the 35,400 men, who paid into the fund on the 31st of December 1911, 25,800 were insured according to the highest legal wage:—5 Marks a day. A member so insured received 3 Marks a day as sick aid, the father of a family of three children 3·75 Marks. About 20,000 of those insured belong also to the subsidiary Sick-relief Funds from which they receive additional aid up to 3 Marks a day, so that it is no uncommon case to find a sick man drawing 6 Marks a day from the various funds. In 1911, the subscription of members amounted to 1,342,000 Marks, those of the firm to 670,000 Marks. During that year 907,000 Marks, were paid out:—to doctors and nurses, for medicine and surgical appliances and bandages, for burial money, &c. The fund has already paid out 1,222,000 Marks in sick-relief. The firm possesses its own hospital to which members of the Sick-aid Fund have the first claim. It owes its existence to the war of 1870/71, when Alfred Krupp caused infirmary barracks to be erected, with 100 beds for wounded soldiers, and which he handed over to the works in 1872. The hospital has been considerably enlarged in the course of time, and wards for the workmen's wives and children were added in 1888. There are now 355 beds, 272 for men, 45 for women and 38 for children. The wives and children of men at the Cast Steel Works are received at lower rates than others. The hospital was further completed by the establishment of a Dental Department by Friedrich Alfred Krupp in 1903. All the members of the Sick-aid Fund can make use of it, and the number of patients rose from 14,760 in 1903 to 28,607 in 1911.

The provision for pensions, which in 1853 formed part of the Sick-aid and Burial Funds, had at first no definite form; it was only intended for relief in cases of total disablement, and it was dependent on the surplus money of the Sick-aid Fund. But in 1858, rights to pensions in the form of life-annuities were introduced, so that the foundation of the Pension Fund must be dated from that year. It was still, for the time, connected with the Sick-aid and Burial Fund, and the payments for these three different objects were levied in one sum. At first, the men were divided into three classes, according to their length of service; if a man were unable to work after a service of 35 years and upwards, he received his full pay; after 25 to 35 years two-thirds; and after 20 to 25 years one half of the average pay lately received, in so far as it did not exceed 40 Silbergroschen a day. A man could claim his pension after 20 years, even after 15 years, in cases of exceptionally heavy work, for instance, if he had been employed at the furnaces all that time. The widow of a pensioner or of one entitled to receive pension, received two-thirds of her husband's. Those disabled by accident received their full pay as pension from the firm, their widows also received two-thirds of this pension. Other widows were relieved out of the Pension Fund. This provision for pensions was followed out, until the "Sickness Insurance Act" came into force. This law necessitated a separation of the two branches of insurances, and on January 1st 1885 the Workmen's Pension Fund of the Cast Steel Works became an independently organised fund, which took over the money collected by the old Sick-aid Fund, to the amount of 1½ million Marks, and all the already existing claims to old age pensions. The statutes of the Pension Fund were now organised in a manner more appropriate to the general principles of insurance, yet on the basis of the existing institutions. Contributions were fixed at 1½ per cent of daily wages not exceeding 4 Marks, to which the members contributed at the rate of ⅔, to ⅓ from the firm; the pensions were no longer regulated by classes, but by the exact length of service. At the same time pensions for widows and orphans were introduced; a widow's pension being fixed at one-third of her husband's.

The regulations of the Pension Fund have been frequently extended and improved, for the most part to meet the wishes of the members. In 1886, partial pensions were introduced for partially disabled workmen, who could do what is called pensioners' work in the factory, if otherwise they had served long enough to be entitled to a pension. The standard was raised from 4 to 6⅔ Marks a day's earnings, or 2000 Marks a year, and widows pensions were raised to 50 per cent of the husbands'. To meet the increased expenditure, the firm raised its contribution to a sum equal to that paid by the members, that is to say, it doubled the amount previously given. In 1895, after an examination of the financial state of the funds, the contributions, both of employer and employees, were raised to 2½ per cent of the earnings, so as to guarantee the lasting solvency of the fund. It was also resolved to pension off men who had attained their 65th year, without demanding a certificate of disability to work; in any case, if their years of service gave them a claim after 40 years' service. According to the statutes now in force, pensions given to workmen disabled after 20 years' service, or, in cases the work is exceptionally heavy, after 15 years' service, run to 40 per cent of the average earnings, if these do not exeed 2000 Marks a year. With each subsequent year of service the pension rises by 1½ per cent, till it amounts to 75 per cent. The widow's pension amounts to half her husband's; a fatherless child's under 15, to 10 per cent of its father's. The maximum pension for widows and children is 90 per cent. For orphans, 15 per cent is paid. For instance, a pension for 5 Marks daily earnings and 20 years' service is 600 Marks, for 40 years 1050 Marks, for 6⅔ Marks, earnings, 800 Marks after 20 years', and 1400 Marks after 40 years' service.

At the end of 1911, the Pension Fund had 34,851 members, there were 2774 male pensioners, 1641 widows, 774 children and 204 partial pensioners, so that a total of 9800 persons were provided for by the fund, and the amount paid out in that year was 2,209,171 Marks. The average amount of a man's pension in 1911 was 830·66 Marks, to which must be added half the old age pension from the state, averaging 129·50 Marks, making a total of 960 Marks. Annuities and additional grants to small pensions from the Old Age Fund are not included in this calculation. Pensions to widows and their children averaged to 455·38 Marks. By the end of 1911, a total of 26,500,000 Marks had been paid out in pensions. The reserve fund amounts to 24,500,000 Marks. In order to strengthen and insure the prosperity of the fund, the firm has, from time to time, made handsome donations, besides its large regular contributions. These have amounted, in the time from 1895 to 1911, to a total of four million Marks; besides this the firm pays all the costs of management.

The Sick-aid and Pension Funds are doubtless the creations in which Alfred Krupp's noble conception of the relation between master and men, of the duty of an employer, of the rights of a workman to something more than his hard-earned wages, are more clearly visible than anywhere else. The Sick-aid Fund which he established and developed, is second to none in the provisions it makes for its members. When the Pension Fund was established more than 50 years ago, no one could foresee the ultimate extension of the Cast Steel Works, nor had Krupp any example or experience to guide him in his first attempts to establish old-age insurance for his workpeople. His good will and rare liberality found many difficulties to cope with, and no common share of self-reliance was needed to call such an institution into being at such a time. The frequent changes and improvements were natural phases of its development. The improvements bear witness to the readiness with which the master lent an ear to the wishes of the men, whenever, and in whatever measure circumstances permitted. From the very first, the principle has been maintained of preserving that which had proved good, and of replacing the antiquated by what was suitable to present requirements, all, so far as possible, in deference tothe wishes of the members. It is Alfred Krupp's imperishable merit that he realised so early the idea of old-age insurance.

Alfred Krupp began to provide workmen's dwellings in the early 'sixties. The building of the first houses was not forced on him by local scarcity of dwellings, but by the wish that some of the foremen and workmen should live in the immediate vicinity of the works. The works were then so small that a sufficient supply of labour could be drawn from the little town of Essen and the neighbouring villages, but a radical change took place with the enormous extension of the works which began in the' sixties, and continued without interruption till 1874, and brought with it a constant increase in the number of workmen. The works employed 2000 hands in 1860; in 1867 the number had risen to 6900, in 1871 to 8900, and in 1873 to 11,600. This influx of artisan population caused a proportionate rise in the demand for dwellings, which it was extremely difficult to meet. Alfred Krupp tackled the difficulty with his wonted energy, and though the profits he was making did not seem to justify the outlay, he strained his credit to the utmost, and, in the shortest possible time, erected large workmen's colonies, with upwards of 2500 dwellings at a cost of over 12 million Marks. Nothing of the kind had ever been seen or heard of before. By this means the Krupp workmen obtained plenty of good cheap dwellings, and the secure tenancy thus vouched for was a great boon, especially for large families, at times when a sudden rise in the demand for dwellings causes a corresponding rise in rents. Alfred Krupp's object in doing this is explained in a letter written in 1871:—"It must not be forgotten," he wrote, "that the principal object of these colonies is to provide healthy dwellings, at the lowest possible rate, for the poor, and for those whose means are limited. The dwellings are not intended for those to whom a few Talers for rent is a matter of indifference, and who therefore seek more convenient and prettier dwellings. But faithful workmen of the good old steady sort cannot fail to be satisfied with this provision, and with proportionate support from the Sick-aid and Pension Fund."

The colonies of "Nordhof", "Westend" and "Schederhof", all in the immediate vicinity of the works, and "Cronenberg", the largest of the Krupp colonies, situated to the west of the works, with more than 1400 dwellings, were all built between 1870 and 1874. The "Baumhof" was built at a greater distance in the fields; the cottages were small, and with their little cowhouses and pigsties had quite a rural character. Family dwellings were also provided at the outlying works. At the colliery Hannover, colonies were built at the two pit mouths. In 1874, the firm could dispose of 3200 dwellings. Barracks were also built, where 600 single men could lodge, and double that number could have their meals. Between 1874 and 1887 no more workmen's dwellings were built, as the depression of trade and industry during that time, caused many of the existing ones to stand empty.

Of the dwellings built before 1874, about half consisted of two rooms, a living room and a bed room. The other half had three rooms, and a few had four. Both the exterior and the interior of these dwellings bear witness to the far simpler mode of life of those days, moreover Alfred Krupp wished first of all to help those whose wages were the lowest. We shall speak later on of the way in which this idea was further carried out.

Alfred Krupp insisted on these dwellings remaining the property of the firm, so that their object could be permanently secured. They were therefore never sold, but always let to tenants who paid a rent considerably below the local standard. Nor was there any fixed plan in the erection of the buildings. Sometimes in the immediate vicinity of the works, where space was precious, large houses containing 4 or 6 dwellings were built; and where more space was available, small cottages were put up, as in the Baumhof and at the colliery Hannover. The larger colonies, Cronenberg and Schederhof, have parks and, wherever it was possible, avenues of trees were planted and small gardens and bleaching grounds were provided.

A comparison of the architecture of the older colonies with those of the present day gives an instructive picture of the progress of artistic feeling in Germany during the last forty years. The buildings dating from the early seventies are plain and serviceable without any pretensions to aesthetic beauty. Where the rows of houses are not varied and enlivened by rows of trees and borders of grass, the effect is dull and monotonous. But who can reproach the builder with this? It was but a beginning, and at the time domestic architecture was dull and monotonous everywhere. Nevertheless, Cronenberg, in spite of its grey, unadorned houses, presents an imposing spectacle by the liberality with which the plan is carried out, by its avenues, grass-bordered streets, and large central park, while at every cross road we catch glimpses of the works through the trees. It still remains as Alfred Krupp planned it, and as we wander through it to-day, we cannot but recognise the rare and generous spirit which he impressed on all that he undertook.

The third creation of Alfred Krupp is the Supply Stores. They were founded in 1868, when the firm took over the management and the liabilities of the Essen Supply Stores, which were then in difficulties. The object of the Stores is to procure for the workmen and employees of the firm, all the necessaries of life in good, unadulterated, and cheap form. Here too, he thought first of the neediest. He writes in 1873:—"The Stores are, in the first place, intended to provide, as cheaply as possible, for the needs of those workmen who have to manage on the lowest wages. That was my object in founding them. Since that time, they have expanded in all directions. Fancy goods have been added to the necessaries of life. I am desirous that they shall meet every reasonable want, but, in the gratification of such wants, it must not be forgotten that the poorest must be thought of first."

The Supply Stores comprise many departments, in which are found:—groceries, liquors, drapery of all kinds, household articles, furniture, ironmongery, &c. There are also tailoring and shoemaking departments, butchers' departments with shops of their own and a bakery, which supplies the grocery departments. The bakery is the oldest of all the institutions which provide the workmen with food. Its commencement dates from 1858. The present bakery, fitted up with all the modern inventions and appliances, was built in 1904–1905; the meat department was also almost entirely rebuilt in 1908. The Stores have many branch establishments, not only in Essen and the immediate neigbourhood, but also at the outlying works; for instance, at the Annen Steel Works, at the collieries Hannover & Hannibal, at the Friedrich-Alfred-Hütte, and at the iron-ore department in Siegerland. At all the stores none but the workmen and employees of the works have the right of purchasing. No credit is given, so that the incurring of debts is avoided. The prices are moderate, regulated, as was said before, by the greater or less indispensability of the goods. With the increase of business, surplus profits came in, which since 1890 have been divided among the purchasers as discount on their purchases. The discount is reckoned when the yearly balance is made, and paid at the beginning of October, so that the recipients can lay out the sum on the needs of the coming winter. In 1910–11, 43,897 purchasers' books were issued. The lists of discount payment show that in 1890–91 a workman purchased annually goods to the value of 345 Marks, and in 1910–11 to the value of 681 Marks. This makes 28 per cent in the former year and 41 per cent in the latter of a workman's annual average wages. But the benefits resulting from the stores do not stop here. In a large town like Essen, where a great proportion of the population are dependents of the Cast Steel Works, the Supply Stores, by selling good wares at moderate prices, regulated according to the indispensability of the article, have a great influence on prices in general, especially at times when a rapid rise of industry and consequent increase of the population might easily produce an exaggerated rise in prices.

In connection with the workmen's dwellings erected in the early 'seventies, Alfred Krupp established a nonsectarian elementary school. It was near the colony Cronenberg, and comprised eight classes for boys and girls. The nonsectarian character of this school, dating from the beginning of the confessional struggle, (the Kulturkampf,) was maintained till 1903. In that year the parish of Altendorf, where the school was situated, was incorporated with the town of Essen, into whose hands the management of the school passed. Krupp had already supplied the parish of Altendorf, which was unable to cope with the growing want, with several school buildings, and had placed them at the disposal of the parish, so as to prevent the over-crowding of the existing class rooms. All these schools are now managed by the town of Essen; except an Industrial School which is still supported by the firm. This is a school where girls over 14 and married women can be thoroughly instructed in all feminine handiwork, such as plain sewing, the use of the sewing machine, dress making, embroidery and other arts and crafts, and ironing; not only as domestic occupations, but also as a means of livelihood. The school is intended, in the first place, for those belonging to the works, but so far as space and the staff of teachers permit other pupils are admitted. A new school building was provided in 1907; the present number of pupils is about 380. There are needle-work schools for children who have not left school, in which knitting, crotchet, and plain sewing are taught twice a week. There at present 3500 pupils.

In 1877, a Life Insurance Company was founded. Its object is to encourage life insurance among the employees of the works, and to facilitate the effecting of insurances by acting as agents. At the same time, a fund was established which reduces the costs by giving discount on the premium; it also advances money in cases of need, or at certain periods pays the premium so that the policy shall not be forfeited. Arrangements were made with a number of insurance companies, and the reduction in price thus effected was paid into the fund. This institution has had a most beneficial result. By its means, a total of 17,045 insurances have been effected, for a capital of 35,877,500 Marks, and for a total of 2477 cases, 3,927,200 Marks have fallen due. There now exist 9431 policies, representing a capital of 22,170,400 Marks, a discount of from 5 to 8 per cent on the premium is allowed to members of the fund. Advances of money to help policy-holders were made last year to the amount of 10,000 Marks. Alfred Krupp, who, in the General Rules and Regulations, of 1872, had emphasized the importance of life insurance, took great interest in the work, and at once endowed it with a capital of 50,000 Marks.

The series of provisions for the welfare of his workmen, made by Alfred Krupp, closes with the Life Insurance Fund, which, in a certain sense, completes the Pension Fund. His keen, experienced eye had perceived what, at that time, was necessary for the amelioration of the condition of the working classes. He called the required institutions into life on the most comprehensive scale, and we have every right to call him a pioneer on a road of unexampled generosity. His work, with its unnumbered blessings, paved the way for his successors' achievements, and his creations:—the Pension Fund, the housing of workmen, and the Supply Stores still form the foundation stones on which rest the provision for the welfare on the employees of the Cast Steel Works.

# 1871—1887.

## THE COMMERCIAL CRISIS OF 1847.

The victorious close of the war of 1870/71 had brought unity to the German people in the newly established empire. North and South were at last joined once more. The Krupp guns had proved their worth in the struggle, and if, in the words of the adversary, the German artillery had been the weapon that decided the fate of the war, Krupp certainly had a right to claim some of this recognition for himself.

After peace was made, a general advance took place in every branch of economic life, and brilliant times seemed to be in store for German industry. This was especially the case with the iron industry, owing to the necessary renewal of railway rolling stock, and the extension of the railway system. There was abundant capital at the disposal of trade, owing in part to Government loans being repaid; the coinage reform increased the currency. The price of all manufactures rose considerably. As in all times of great increase of trade, there were loud complaints that industry could not supply enough. Everything combined to promote the enlargement of existing works, and to bring about the founding of a number of new establishments. The same symptoms were to be observed in all the countries of Europe. Ultimately a positive fever for founding enterprises spread in all directions, and over-speculation, which could not possibly continue, took possession of the money market.

The Krupp works too, advanced at this time more rapidly, than ever before. Extremely vigorous activity prevailed in all branches of production both of material for transport and other industries and war material, in purchasing property, and in providing for the social betterment of the men. The number of those employed at the Cast Steel Works rose from 7000 in 1870 to 12,000 in 1873; at the outlying works from 1200 to 4000. But here, as elsewhere, a too unlimited confidence was placed in the times, sufficient attention was not paid to strengthening the financial basis of the rapidly growing enterprise, and little provision had been made when the state of trade and commerce suddenly collapsed. In the course of 1873, the first signs of a change appeared. They proceeded from the money market, and were first noticeable in Austria. But the depression soon spread to Germany and the other European countries, and a ruinous industrial crisis soon set in, which affected the iron industry in a special degree. The demand sank rapidly, the more so, as the railways entirely ceased ordering for a long time, and the foreign market soon closed too. Prices went down very low, and dark days began both for employer and employed.

The effect of the depression was considerably aggravated in Germany, by the fatal change in the German customs policy to free trade, which had been preparing through the years of prosperity, and now came into force just at the unfortunate time when—even without this last calamity—the whole economic life of Germany was shaken to its foundations. The German iron industry had been developing favourably ever since the Tariff Reform of the 'forties, protective duties had given it a firm footing, on which the processes of manufacture long established in England could be introduced quickly and uninterruptedly. These satisfactory results had encouraged the wish for further advance, and the endeavours to get a share in foreign trade led to the making of commercial treaties, the most important of which was that made with France in 1865. By this treaty, the duty on pig iron was reduced to 5 Marks a ton. In 1868 further reductions in the duty on iron were made. Free trade notions gained ground more and more, and the general prosperity of the time following the war strengthened the tendency. It is true that far-seeing men raised their voices in protest even then, and pointed out that in times of depression in trade, the cheaper products of foreign countries would flood the German market, while Germany could not reach those foreign countries which do not produce iron without passing the customs barrier. But the liberals carried the day by passing the law of 1873. This law entirely repealed the duty on imported pig iron, lowered the rates for manufactured iron, and decreed that the reduced rates should also be abolished on January 1st 1877.

So the German iron industry, which by the demands of the home market and the favourable conditions of the foreign markets, had, during the last few years, risen far above the limits of the normal home demand, not only had to face a greatly reduced possibility of home sale at the beginning of the crisis, but it also lost its sale in foreign markets, and was threatened with foreign competition in its own country; for foreign makers would certainly not overlook this opportunity of disposing of their over-production. The effects of this combination of unfavourable circumstances were really ruinous for the German mining and iron industries, and the more firmly foreign competition planted itself in Germany, the more hopeless was the prospect of improvement. Though the output of coal, and the production of pig iron decreased but little in the next few years, it was only because the factories did all they could to keep going, so as to ward off greater evils, even if they made no profits, or worked at a loss, as was only too often was the case. But the number of men employed was already greatly on the decline; in the coal-mining district of Dortmund it sank from 84,000 to 74,000, *i. e.* about 12 per cent, in the Prussian iron works from 22,300 to about 13,000, *i. e.* 42 per cent. The bad times were still more noticeable in the returns of the works and the wages paid. The prices of the products of collieries and iron works had gone down very low. Hard coal dropped from 11 Marks to 4·20 Marks, pig iron from 115 Marks to 55 Marks; and also the products of rolling mills fell to half their former price. The big blast furnaces of Rhineland and Westphalia: Phoenix, Hörde, the Bochum Verein, the Dortmund Union, could not pay any dividends for years, the price of the Bochum shares, for instance, fell from 230 to 24, of Phoenix, from 222 to 33, of Hörde from 145 to 24, and of Dortmund from 171 to as low as 4. Even such wealthy enterprises as the Cologne Mining Company could at times pay no dividend. The whole people must suffer when such an important part of economic life is in distress, but it was especially the working classes who had to feel the effects of the bad times. For the miserable state of industry and the want of work, pressed heavily on the wage-earning class. Among collieries—where the average annual wages in 1873 had been 1700 and 1800 Marks there was a sudden drop to 1100 and 1000 Marks. Of course there was a similar decrease of wages in the iron industry. Even the Krupp works,—where the branches manufactured paid in part higher wages,—showed on an average a reduction of 25 per cent. What this means in general can be seen from the following figures : the total paid in wages in the Krupp works in 1873/74, amounted to a round sum of 14·5 million Marks; in 1878/79 to 7·6 million Marks. The Gutehoffnungshütte paid their men a round sum of 8·7 million Marks in 1872/73, and in 1877/78, 4·6 million Marks. This is a reduction to almost one half, the effects of which spread to all other branches of work, agriculture and trade.

This state of things, which got worse and worse every year, reached its lowest point in 1878/79, after the last remains of the duty on iron had been abolished at the beginning of 1877. It is quite plain, that this unchecked competition of foreign trade, which could produce under more favourable conditions, was the cause above all others, which destroyed all faith in the possibility of improvement, and thus really hindered improvement. This view of the matter spread more and more, and public opinion again inclined to the idea of protection for home industry, it was hoped that the re-introduction of protective duties would secure the home market for German products. The Government, which had just let things take their course in 1877, now resolved after a long wait, to make a move; free trade policy was abandoned, and moderate import duties were established. The Customs Tariff Law of 1879 fixed the lowest duty on pig iron at 10 Marks a ton; on iron bars at 25 Marks, and on more finished iron and steel products proportionately higher rates were fixed. The renewal of prosperity in the iron trade was to bring relief to the mining industry in general, to coal mining in particular. And truly the enactment of this law marks the turn for the better, though the recovery was slow, and was arrested several times for a longer or shorter period. The advance, indeed, was not rapid until 1887; then in the middle of the 'nineties that powerful upward movement began, which placed Germany first in steel production, and then in pig iron second among the iron producing countries of the world—immediately below the United States of America. Germany, at present, holds the third place in the output of coal, but is rapidly gaining on England, which has the second.

The Krupp firm felt the depression in trade first in its production of material for transport and other industries, especially railway material; the sale fell quickly to three-fifths the amount sold in 1873/74. War material soon followed suit, when the orders resulting from the war were finished. The number of men employed at the Cast Steel Works went down from 12,000 to less than 8000 and did not regain its former height till 1886. The factory made very small profits; in some years even there were considerable losses. Besides the general effect of the reaction in trade, special causes helped to make the position of the firm very critical. The depression occurred at a time when the financial basis of the enterprise was totally insufficient. The great extensions made in the Cast Steel Works, the erection of 2500 workmen's dwellings, and lastly, the large purchase of coalmines, iron-ore concessions and blast furnaces had tied up an enormous amount of capital. The profits of the factory could only cover a small part of this outlay. It had been necessary to strain the firm's credit greatly. But Alfred Krupp, who in managing technical matters was so cautious and circumspect, neglected to place his credit on a sound basis at the right moment, by raising a permanent loan. As things stood before the crisis, when abundant capital was ready at the call of industry, and the factory was in a prosperous state, it would have been an easy matter to get the necessary funds on favourable terms. Allowance must be made for Alfred Krupp, if, in the universal rush of progress, he put aside the thought that affairs might take quite a different turn. It must, however, be admitted that his self-confidence led him lightly to an extreme optimism where money was concerned, that was part of his paternal enheritance. And though this optimistic way of taking things was in general beneficial for his enterprises, still in this case, it must be confessed, the risk was not necessary, and it would have been easy to find a safer way.

So the firm's credit with banks and its name on bills was strained to the utmost, when the storm broke out and dashed the hopes of large profits from the factory to the grounds for years to come. Public confidence was shaken to its foundations, capital drew timidly back from enterprise; and Alfred Krupp just as the crisis began, committed the imprudence of making further purchases, and applying to the banks for help, which gave a very bad impression. So his earlier resources suddenly failed him, and his situation was one of extreme jeopardy. In this dilemma nothing remained for Alfred Krupp but to raise a large loan on a mortgage of the factory, so as to meet his most pressing liabilities. But the money market was no longer willing and what would have been quite an easy matter shortly before, was now only effected with difficulty and at a great loss. After tedious negotiations partly conducted by Alfred Krupp in person, in 1874 it was possible to come to terms with a combine of Berlin banks, for a loan of nominally 30 million Marks. The Royal Prussian Seehandlung, which had placed itself at the head of the combine, helped in the most obliging manner to mediate the loan. The rate of interest was fixed at 5 per cent, and the other conditions—owing to the state of the money market—could not fail to be hard and oppressive for the factory. The rate of repayment was at 110 per cent, whereas the banks would only accept the loan at 90 per cent. According to the terms agreed on, the whole was to be repaid by 1883; the yearly instalment rose rapidly to six millions for the last three years. One result of these loan negotiations was that Meyer, who had represented the firm in Berlin for many years, and who held an excellent position in financial circles there, was appointed a member of the Procura, so as to restore the tottering credit of the firm. Hard as the terms of the loan were, and bitter as it must have been for a man like Alfred Krupp to accept them, still it must be acknowledged that the loan was help in need, rescue from great distress.

The balance sheets of that time show that, even after the loan was raised, the financial position of the firm was still very serious. Though the immediate danger was averted by the loan, the state of things remained insecure and unsettled for some time longer. The floating liabilities were still very considerable; there was no prospect of anything like large profits, and yet the repayment of the loan had to begin very soon. But fortune was kinder to Alfred Krupp than she had been to his father, who had succumbed to financial troubles. While Germany, suffering as she was herself in the commercial depression, could give no help, it came from abroad. The great esteem in which Krupp manufactures were held throughout the world, was now to prove its worth, and during the 'seventies it brought several orders for war material from foreign countries—very considerable ones indeed for those days—which gave the factory work for some years. And when these orders were finished, the extensions of railways in the United States of America at the beginning of the 'eighties brought in such large orders for rails, that the output of the Bessemer shop reached the enormous annual average of 173,000 tons from 1880 to 1883. The important foreign orders enabled the firm to fulfil its obligations without further shocks to its finances, after it had succeeded in converting the loan, in 1879, by an extension of the date of repayment, and thus lightening its load. This converted loan amounted to

22·5 million Marks, also repayable at 110 per cent, but it was accepted by the banks at 102 per cent. According to the terms of the contract, it was to be finally paid off in 1899, but repayment was actually completed in 1887, before Alfred Krupp's death. The experience gained in the year 1874 was not without lasting effect; the assuring of the financial fundament of the enterprise and the maintenance of perfect independence in this respect, have, since that time, been rigidly upheld as guiding principles in the business management of the firm.

It is worth while to look a little more closely into the help which came from abroad at that critical time; and thus to get an idea to what extent the development of the Krupp works is owing to foreign trade. Regular business connexions with foreign countries began early. In the second half of the 'thirties, they comprised half the sale, and in the 'forties, this branch of business increased so much, that on an average, 66 per cent, in some years, even 70 to 80 per cent, of the output of the Cast Steel Works could be sold abroad. This is shown in a much higher degree after the critical period from 1874 till 1890. Between 1875 and 1889, 64 per cent on an average of the total output of the firm went abroad. In one year it even rose to 75 per cent. We may therefore say that until 1890, the progress of the Cast Steel Works mainly depended on foreign orders, in comparison with which home orders in many years were quite insignificant. Since that date the proportion has gradually changed in favour of the home market, through the great increase of home demand for iron goods; moreover, by the adoption of the Thomas process in the new steel works and rolling mills at Rheinhausen, the Friedrich-Alfred-Hütte, in 1905, a great extension of the programme for production en masse has been made.—Sale abroad, however, is still very considerable. Since 1890 it has amounted on an average to 33 per cent, and in one year to 48 per cent.

But when we take war material alone, foreign countries have a much more marked importance for the Krupp works at the present time. Though on the one hand, the factory must always unreservedly and gratefully acknowledge the warm support which has always been accorded to it at home, from the time it took up the manufacture of guns, still it must be admitted on the other hand, that foreign countries also contributed largely to promoting that manufacture as early as the 'sixties, and that the first practical success in this field was gained on foreign soil. From 1860 to 1871 the orders executed for abroad in small guns under 10 centimeter caliber did not come up to the home orders—2462 guns as compared to 3244—but more than twice as many guns of big caliber were ordered abroad than at home—1165 compared to 560. In any case the financial share of foreign countries was greater. How extremely valuable the support was, which the Cast Steel Works continued to receive from abroad for many years after the depression of 1874, may be judged from the fact that from 1875 to 1889 not less than 84 per cent, in some years even as much as 92 per cent, of the total output of war material was for foreign orders. A considerable share has also been sent abroad in later times. From 1889 till 1904, 51 per cent and in one year 87 per cent, from 1904 to 1909, 54 per cent, with a maximum of 65 per cent have gone abroad.

The Krupp firm may well point with complacency and justifiable pride to the long series of successes abroad, represented by these figures. What its products have done for the commercial life of Germany, and the position of German industry abroad is clear, and needs no further proof. But these figures show also, how false the ever-recurring assertion is, that the Krupp firm owes its prestige simply and solely to enjoying a "monopoly" at home. In the first place, those who assert this, forget the material for transport and other industries, in which Krupp, like every other industrialist, has to face open competition, both home and foreign. This branch comprises more than half the output, and occupies at least two thirds of the workmen. On the other hand, as regards war material, the firm must, in this field too, encounter the competition of German works, both private and belonging to the Government, in many of its products. The Cast Steel Works have gained its standing abroad in an open struggle for excellence, merely by the cheapness of its products; only by this means can it maintain its standing. The more recognised that excellence is, the greater the demand for Krupp war material abroad, of course, so much the more efficient will the factory be for Germany. For thus the works will keep in touch with all that is done in this domain all over the world, and constant competition will bring many new ideas and much fresh experience. Lastly foreign business has naturally had its share in the enlargement of the factory buildings and its general productive power, which may be of great service to the country in times of need. The factory gave a proof of this readiness and ability to serve the country, soon after the close of the Franco-German war, when it was possible, by the help of the Cast Steel Works, to effect the urgently required re-armament of the German field artillery, in the short space of one and three quarters of a year. The works have given such proofs of efficiency again and again in the course of time, when it was a case of satisfying a great and pressing need in the German naval or military departments with the greatest possible promptitude.

# THE DEVELOPMENT OF ORDNANCE UNTIL 1887.

Immdetiately after the war with France experiments were resumed in Germany to design and build a field gun of higher efficiency. As it was, a part of the German field ordnance stood in need of being replaced after the exertions of the campaign. The conviction, however, which was gaining ever more ground in military circles, in spite of the successes obtained by the German artillery in the field, the conviction that the growing improvements applied to the infantry rifle also demanded the adoption of a more powerful gun, proved decisive. The destructive effects of the chassepot gun during the Franco-German war had only tended to strengthen it. Krupp had for years already been working at attaining the goal in view. As early as the end of 1868 he offered for trial a gun of greater range and of a less curved trajectory, to replace the four and six-pounders hitherto in use. He had designed this gun after long and minute experiments, utilising in its construction the experience he had gathered from his built-up guns. These experiments had taught him, how erroneous the prevailing opinion was, that with rifled breech-loading guns the weight of the powder charge must not go beyond $^{1}/_{12}$ to $^{1}/_{10}$ of the weight of the projectile, without impairing the accuracy of fire. He, on the contrary, considered, that it was perfectly admissible with the cast-steel gun to raise the charge, and his conclusion was, that in doing so, the effectiveness of the gun could be considerably augmented. And after having arrived at this result, he also hoped to realise the project, then much deliberated, of constructing a single type of gun for field ordnance, since the power of the new gun would be sufficiently effective against such aims as commonly occurred in field warfare. In a report, dated July the 9th 1872, he wrote on this subject:—"It is impossible to unite all demands in respect of efficiency of the projectile in one caliber. For the ordinary purposes of field warfare a small 8-cm caliber will be sufficient against living objects, this besides offers the advantage, as compared with bigger calibers, of allowing to augment the number of rounds in the limber. When firing at farm houses or villages, also a small caliber will be sufficient, for, in any case, its efficiency will not be great enough against field fortifications, on account of the smallness of its bursting charge, in which cases the object is to destroy earthworks, yet for such purposes the Prussian 6-pounder, hitherto in use, has been as insufficient as the 4-pounder. If indeed so much importance is attached to this kind of effect in field warfare, a special kind of gun, an 8 or 12-pounder howitzer must be introduced. The primary question whether a single type of gun should be introduced or two kinds of guns, ought to have been decided before entering upon any new experiments. Here is a question at bottom, which no experiments can decide". With the new design of his gun Krupp intended to obtain an initial velocity of 1700 feet, equal to 534 meters, as compared with the 323 meters of the 9-cm field gun, or the 341 meters of the 8-cm gun. In order to give the gun tube the necessary strength to resist the increased powder charge, he adopted the jacket system for the 7-cm experimental gun. In this construction the liner tube begins at the front face of the wedge slot, so that this slot itself is worked into the jacket which is shrunk on the liner. This design permitted a more rational construction of the gun tube than the hoop system, for in this the wedge hole traverses the inner tube. The design, besides, had this advantage that it permitted a more thorough forging of the inner tube, and facilitated the exchange of the same. All subsequent experimental guns were built on the jacket system, to which Krupp from that time forward gave the preference, and which by degrees he applied to all gun tubes, changing it for bigger calibers into the jacket-and-hoop system. At first the jacket covered the whole inner tube up to the muzzle, in later guns it was shortened for reasons of design. After February 1871 that design was given to the gun tube which it retained in the new field gun C/73. The guns experimented with, were all fitted with the cylindro-prismatic breech wedge mechanism, which later on was fitted with an oblique vent right through the wedge ending in the axis of the bore. On the 13th of June 1871 the new gun with shortened jacket was handed over to the Artillery Experimental Committee by Krupp, who now did everything in his power to hurry up the trials to be carried out by the authorities, and to get all improvements applied to the new field gun, for the political situation after the peace of 1871 did not seem to him to exclude a fresh breaking out of hostilities, all the more as France was about to adopt a new breech-loading field gun superior in efficiency to that of Prussia. Krupp therefore saw a serious danger in any retardation of the re-armament of the German field artillery, and he did all he could to push on and bring about a quick decision. In the course of the experiments, a second gun of 8·8-cm caliber had been adopted besides the original 7·85-cm gun. Both now were given in 1873 that design with which they were adopted under the denomination of field ordnance C/73. Between October 1873 and January 1874, the Cast Steel Works received orders for 2500 field-gun tubes, and at the same time for the steel-plate sides and cast-steel axles of the carriages required. Until the first of July 1875, that is within 21 months, the whole of the German field artillery was supposed to be rearmed with the new gun. And Alfred Krupp made himself personally responsible to the emperor, to deliver the guns in time. The productive capabilities of the works were put to an extraordinary test by such short notice of delivery, but Krupp did all he could to come up to these obligations, and he indeed succeeded in delivering the guns ordered within that short space of time. This piece of work was a remarkable instance of what the Krupp works meant for the state of defense of the country.

The improvements in the construction of the gun tubes for the new field artillery could not be effected without many previous alterations as regards the projectiles, their forcing arrangements, the powder and the carriages. And in all these things Krupp had a considerable share. In many of these questions he was able indeed to bring his opinion to bear, so for instance in the powder question. As early as 1869, he had selected among coarse-grained powders of various kinds differing in size, shape, and density, one with grains of 6 to 10 millimeters size, and of 1·65 to 1·75 density, as being the most practical, and this really was adopted for the new field guns C/73. He also found out a process of making steel carriage sides for the new gun to replace the old wooden ones. Such carriage sides were at first, for the experimental guns, made from steel plate to the edges of which angle-irons were riveted to obtain greater stiffness. But already in the winter 1868/69 Krupp succeeded in pressing such carriage sides from one piece of steel plate with a flange all round. No riveting being necessary now the carriages could be made of lighter weight. A hand-worked press was at first used in making such carriage sides, but when a greater demand for trial guns came in view in 1872, a press was built at the works operated by hydraulic power. From January 1873 this press turned out steel-plate carriage sides, such as were adopted for the carriage system C/73. In the trials carried out during the years 1868, the factory had used shells with a more elongated point and $^1/_2$ caliber longer than those hitherto in use, with ogival head. They had a thin lead coating which was later on replaced by a copper driving wire, the cavity of the shell was grooved to increase the bursting effect. The gun sent to Berlin for trial in 1869 was equipped with such shell. As the grooves did not produce the expected results, namely to promote the breaking up of the shell in a greater number of fragments, the Krupp works recommended in 1872 the trial of a shell with a double wall which indeed was adopted in the sequel. Experiments were taken up at the works as early as October 1871 with the use of forged thin-bodied base-chamber shrapnels, for the new field gun. The body of the shrapnel was supposed to act so to speak as a mortar, from which the lead bullets that it contained, were shot out at the bursting point, without the shrapnel body itself being destroyed. Such shrapnels were expected to produce a more regular form of the cone of spread, and a better effect as regards the beaten zone, as compared with the shrapnels then in use, with bursting chamber about the middle or in front. Although this projectile was not adopted in Germany for the gun C/73, but was only introduced for the field gun system C/96, Krupp in his own experiments, had, since 1871, used none other but the rear-burster shrapnel. The manufacture of this shrapnel by forging, which was rather complicated, was abandoned about the middle of 1878, when Krupp succeeded in making shrapnel bodies from steel by pressing and drawing, a pratice still in use. Also in other respects Krupp could not carry his views, so especially in the important question of the best device for forcing the projectile, which at once turned up again, when a higher efficiency of the new field gun was attempted. The trials carried out in 1869 already had shown that for muzzle velocities of the projectile exceeding 440 meters, the old use of soft lead for forcing was insufficient, this metal being to little resisting. From the beginning of 1870 therefore copper wire was used, and in order to give more surface to the forcing action, the number of grooves was augmented from 12 to 18, the lands besides were made narrower, and the edges of the grooves parallel. Progressive twist was adopted so as to obtain a gradual transition into the steep final twist. Unfortunately the proving ground at the works had not a sufficiently long range to test the suitability of the new device by firing experiments with regard to accuracy. The works therefore were obliged to content themselves with the trials being carried out by the Artillery Experimental Committee. This mode of working, however, was rather round about and presented difficulties. The authorithies in many respects worked on other principles of construction than the works, and carried out the trial, as was natural, from their point of view. As they preferred at that time the lead coating to the copper wire for forcing the projectiles, they fired lead-coated shells from guns which Krupp had built for copper wire. It was therefore unevitable that the trials with the guns Krupp had presented for the purpose did not give general satisfaction, and that the great hopes which Krupp had placed on the new device, were only in part fulfilled.

But such experience, which frequently was very aggravating, had its very good effects on the development of the Cast Steel Works. It was this experience above all which decided Alfred Krupp eventually to carry out a plan he had long fostered, to make himself independent of the assistance of others, by establishing a large proving ground of his own. Nowbody, not even officers of high rank that patronized Krupp, understood his plans in this direction. It was considered an uncontested privilege of the State to be the owner of proving grounds. What business could a private industrialist have to own a proving ground for guns? To such objections Krupp answered in a letter written in 1871 to a general, who was a friend of his. This letter is characteristic for the views and objects that actuated him in his plan, as well as for his general mode of thinking. The letter says in this respect: "I do not wish to make progress of manufacture dependent an others, and what must be done for this object, and must be put into practice, must be carried out during my lifetime. I have a great object in view, and I am prepared to sacrifice anything to it. To obtain such end a man must be as convinced of its usefulness and necessity, as I am. He must be so strengthened in his conviction, by the results hitherto obtained, as I am in my endeavours which very frequently have been derided as illusions by men of the profession. After having said this, I have only to assure you that this project is not a fancy of vanity, or an outcome of levity of mind, but a harvest of well calculated effort. We shall in future be able to elucidate questions relating to the efficiency of projectiles, to the resistance of air, to the effects of stone, iron and so forth, in a way, which never before, nor anywhere, has been possible in a like measure, since both the means and the space were wanting. Without having to permit any one to interfere, or depending on the permission and the complacency of others, without being forced occasionally to carry out my trials under insufficient conditions of space, things which inevitably would occur on the grounds at the disposal of the State, I insist on being able at any hour to carry out my trials by my own men and without any interference from others. In this way only we can attain in a short time what in the ordinary course of things would take centuries. The proving ground I wish to acquire should at least be two miles (15 kilometers) long, and if possible one mile wide". As no ground of such size could be quickly found, a plot of land was bought near Dülmen in Westphalia, affording, however, a range only of 6900 meters. This Dülmen proving ground was taken in use in 1873, it was placed under the management of M. Prehn, a noted expert in ballistics, and particularly suited for this post by his experience of many years' standing in matters relating to firing and other experiments. To his management is also due the model equipment of the proving ground near Meppen, which was bought some time after. To the common work of Prehn, the expert of ballistics and Gross, the genius in gun design, is due the progress in ordnance, which in after times enabled the firm of Krupp to take the lead in artillery matters. The insufficiency of range of the proving ground near Dülmen soon became evident, when Krupp began his firing experiments of siege guns, with a view to raise their ballistic power. These trials had to be put off until the year 1877 in consequence of the difficulty to find out and to acquire a larger proving ground. It was not until the 5th of September 1877 that the first round was fired at Meppen from a 15-cm siege gun at 9000 meters range. The equipment of the new proving ground which when it had been carried out, rendered the ground near Dülmen superfluous, entailed much work. In order to obtain a junction to the state railway line, a normal gauge track 3·5 kilometers long, which had to be taken right up to the platforms for the heavy naval and coast-defence guns to be tried, had to be laid down. A supporting frame work for a travelling overhead crane of 75 tons hauling power, had to be built. This platform stood at the beginning of a range, 16·8 kilometers long, to continue which, if need be, to 25 kilometers, provisions had to be made from the first. Such range for instance became necessary, when on the 28th of April 1892, in the presence of the German emperor, a round was fired from a 24-cm gun L/40 C/86, at an elevation of 44 degrees, a range being attained of 20 226 meters. Along the firing line all the necessary arrangements were provided, shelters, signaling appliances, and such for sending messages during firing by means of telegraphs and telephones, instruments and devices for measuring the velocities of the projectiles, and observing the conditions of weather. In the rear of the battery were the necessary storage places for ordnance, powder and ammunition, the shops to prepare the ammunition, the mechanical shops, also the offices for the management of the ground. The increased demands of modern days have necessitated an extension of the original arrangements of the Meppen proving ground, which now has an average width of 4 kilometers, the long supporting framework for the overhead travelling crane, for many year the characteristic feature of the ground, has been pulled down, and has been replaced by three electrically driven 75-ton gantry cranes, moved on rails, which when heavy loads have to be hauled can operate in common. About 4 kilometers ahead of the platform mentioned above, and to the side of the main range, a second battery for heavy guns has been arranged, joined to the former by a railroad and likewise equipped with lifting devices. Along the range, at distances from 500 to 500 meters, shelters and stations for observation have been erected, that are connected by telephone with the stand of the officer directing the fire. A special track for testing ordnance carriages and wagons as regards their resistance and endurance, which is provided with obstacles of the most frequent occurrence, has been laid out. The vehicles are hauled on this track by a locomotive engine. The importance attained in the course of time by the Meppen proving ground becomes apparent by the fact that in 1911, 1500 firing tests were carried out with 386 different guns, in these experiments 9900 rounds were fired, the weight of the powder used was 112 400 kilogrammes, that of the projectiles 742 000 kilogrammes. Armour plates were fired at, aggregating a weight of 1028 tons. The trials carried out at Meppen, however, only form a part of those carried out by the firm altogether. To save time and expense of transport, a new proving ground has been erected recently at the Essen works, measuring 175 meters in length and 300 meters in width. Tests of durability are carried out here for guns and carriages by means of the first-proof firing, also armour plates, thin steel plates for shields to protect field carriages and naval ordnance mounts are tested here, as well as powder and ammunition. A third proving ground its owned by the firm, which came into its possession together with the Grusonwerk. It is situated at Tangerhütte near Magdeburg, and measures 11 kilometers in length and 2·5 in width. Here the trials with guns of medium and small calibers are carried out. The total of rounds fired in 1911 on the three proving grounds belonging to Krupp, amounted to 34600, for these 4512 guns were used, the powder consumed weighed 144300 kilogrammes, the projectiles 989760 kilogrammes.

The freedom of action in carrying out his experiments which Alfred Krupp had gained by the purchase of the Dülmen proving ground in 1873 had given new life to his endeavours in the line of improvements in artillery. He was now enabled to pursue his own path with a view to raise the efficiency of naval, coast-defence and field ordnance according to his own ideas, and also to turn his attention to siege and garrison guns, on which field the experience of the war 1870/71 had afforded much incitement, which besides was increased by the trials to which State institutions had now and again put bronze guns or guns on the cast-iron liner of which narrow steel hoops had been shrunk. On the fitness of bronze as a metal for gun making Alfred Krupp has expressed himself in a memorandum dated April the 21st 1871, in the following terms:—"…..one may say that experience has sufficiently proved that bronze is altogether out of the question to be used with advantage for guns. It will be found that for equal efficiency, a bronze gun of twice the weight will not be safe against expansion as compared with a cast-steel gun that offers complete safety. It will in particular be discovered that bronze will prove to be a danger for the artillery on account of its smaller efficiency, and that bronze guns will everywhere be superseded by cast-steel guns; and one may not assume that foreign countries will not profit of this truth. Nor it is likely that the armies of Prussia and Germany will ever have to face again bronze canon in future wars. Bronze used as gun metal means a waste of men, horses, and material, a waste of forces, that are sacrificed, whereas they might be turned to effective use, if they were applied to artillery equipped with the best and most effective cast-steel gun. In spite of all the inertia of habit and the opposition of prejudice, cast steel has found its way to the front, and has become the most indispensible metal for war and peace purposes. Thirty years ago the introduction of my first cast-steel barrels for rifles met with the same resistance, just as later on the first axles and tyres for many years were encountered by doubts, indifference and objections; and to day all these things are recognised everywhere. Experience therefore teaches to persevere". Krupp combatted such competition by the means he had so often tried, by building cast-steel guns of like calibers as those of bronze and iron, but of such efficiency as it was impossible to attain with these metals. The advantages attached to field guns on the jacketed-tube system, in 1872 originated the plan to change old massive tubes of 15 and 21-cm caliber into jacketed guns by putting new steel liners into them. But as for big calibers the jacket alone did not produce the desired efficiency, Krupp designed in 1874 guns of 28 centimeter caliber upwards on the jacket-and-hoop system which for the first time was applied in 1876 to the German 28-cm guns of 25 calibers length. The principle of this construction is, that one to three layers of hoops, according as the size of the caliber required, were shrunk on the jacket.

The great importance which attaches to the powder question with regard to gun design, has already been spoken of above. The progress obtained in the manufacture of powder has always been an important factor in the evolution of gun design, aiming at an increase of the efficiency of the guns . It was principally in consequence of the trials carried out with prismatic powder for hooped guns that Krupp recognised the importance of the powder question, and its fundamental moment for the improvement of artillery, and he had practically and successfully turned to account his former experience in the trials which resulted in the construction of the field gun C/73. A report drawn up in the course of these experiences says on this subject. "The trials which have in recent times been carried out in almost all states with different kinds of powder, and the numerous trials of the Krupp works have proved, that the difference of composition of the various powders within the usual limits have no essential effect on the properties of the powder, this indeed depends mainly on the size of the grains and the density of the powder. The trials and the experience of the Cast Steel Works in this respect have largely been promoted by their working together from the beginning with the powder factories. Krupp had in spring 1864, for the first time, ordered powder from the powder factories of Ritter in Hamm on the Sieg, whereas before this, he had obtained his small supply from the powder magazine of the State. In the following year, when the powder question was much ventilated, he asked this factory to manufacture different kinds of powder of certain properties for experimental purposes. Through such common work aiming at definite objects, mutual relations developed, which in 1867 took a more definite form manifested by the handing over of the first press spoken of above to the Hamm factory for the purpose of making prismatic powder. The relations existing between the Essen works and Ritter's factory soon were extended to the powder works of Duttenhofer at Düneberg near Hamburg which in 1882 gave a remarkable proof of its productive capacity by the manufacture of brown powder. A certain community of interest thus sprang up between Krupp and the powder works, as the development of artillery progressed. Its consequence was that the technic of powder manufacture took an evolution that in former times was hardly considered possible. In that competition in which the Cast Steel Works had to fight the Armstrong muzzle loaders prismatic powder C/68 had been used with seven perforations and of a density between 1·65 and 1·68. Later experiments had then shown that for guns upwards of 26 centimeter caliber a powder burning even more slowly was more suitable. Trials were therefore carried out in October 1870 with prismatic powder grains with one perforation and of an average density of 1·75. By way of comparison it was intended to try a powder of still higher density, but a press sufficiently strong had to be found first, so that the continuation of these trials was retarded until 1874. The outcome of this eventually was that prismatic powder with one perforation and of a density of 1·75 proved to be the most suitable. It was adopted in Germany under the mark P.P. C/75. The attempts of the powder factories to produce a powder of the slowest possible conflagration leaving the least possible residue resulted in 1881 in the brown prismatic powder C/82, which contained little sulphur and coal only feebly charred. With this kind of powder the trials were commenced at Meppen in 1882. Equal charges of the powder C/82 and C/75 showed for the former a higher muzzle velocity attended with lower gas pressure, so that guns of bigger calibers could be given a greater charge, while the maximum gas pressure remained the same, and therefore produced a much higer efficiency. Owing, however, to the slowness of its conflagration, brown powder was ill-suited to the short guns of field and siege artillery. But in order to raise also the efficiency of small caliber guns, a coarse-grained powder, in which ammoniac-salpeter formed an ingredient, was used, denominated C/86, soon afterwards also a prismatic powder of the like composition. The efficiency of the powder C/86 was indeed superior to that of C/82, but besides showing a certain irregularity in its effect, it had a noted tendency to attract moisture and therefore did not come into general use. On account of the feeble amount of smoke it gave off it formed an intermediate phase of development, which led to the smokeless gun cotton powder that succeeded it.

The progress made in powder manufacture made it possible to raise the efficiency of the gun through lengthening their tubes. Although Krupp had become early aware of this possibility, technical and tactical considerations stood in the way, and obliged him to proceed only gradually in the lengthening of the guns. So from 18 calibers in 1864, one passed on to 20 calibers in 1866, and to 22 calibers in 1868, when prismatic powder was introduced. In 1874 the length of guns rose to 25 calibers, and finally in 1880 28-cm guns L/35 were built, after experiments had been made in 1879, with a view to examine the effects of powder in two 8,7-cm guns L/50. Since slow-burning powder showed a higher gas pressure towards the muzzle, the front third of the inner tube which hither to remained without hoops, had now such hoops shrunk on right up to the muzzle, for guns of 35 calibers length. When the still slower burning powders C/82 and C/86 were adopted it was attempted in 1886 to lengthen the guns by 5 calibers more; such guns were introduced as C/89 L/40.

Another way of improving the ballistic properties of guns was pursued, that of raising the weight of the projectile; there was a double object in view. The one was to obtain a higher sectional density, and consequently a flatter trajectory, and less decrease of the energy of the projectile. The second, to get a greater bursting effect on impact through the possibility of using a greater bursting charge. Such increase of the weight of the shell, however, required a corresponding increase of length, which for the elongated shell C/69 hitherto had been $2^1/_2$ calibers. Such elongation could, however, not be carried out without considering two other factors, a proper mode of forcing the projectile in the bore, and the accuracy of fire. The longer the projectile was made, the more difficult it become to obtain a regular forcing in the bore, and consequently to ensure accuracy of fire, especially with increasing twist. As unequal impressions were produced on the front and on the rear driving band, the diameter of the front one was reduced, and the diameter between the lands of the shot chamber was made equal to it, so that the rear driving band could come right up to the origin of the rifling. In this way, about the middle of the year 1874, originated the rifled shot chamber with double juntion cone, which shortly after was transformed in the conical and rifled shot chamber. These experiences however had shown that the front copper band played no part in the forcing of the projectile in the bore, that all required of it was, to keep the projectile well centred between the lands, and that the rear copper band alone was sufficient to force the projectile. By this discovery, which was made towards the end of 1874, a prospect was opened for the use of longer projectiles, which had so long been desired. Shell up to five calibers long consequently were tried on the proving ground at Dülmen between 1874 and 1876, in the course of which trials the further discovery was made about the beginning of 1877, that a front centering copper band could be altogether dispensed with, and that a swelling worked on the projectile was fully sufficient. By these trials the principles were evolved for the proper mode of forcing and the lengths of projectiles, that have remained valid until the present day. This was a step forward of the utmost importance for the further development of artillery. A possibility was thus given through raising the length, and consequently the weight of the projectiles, to obtain ballistic effects also with guns of small calibers that hitherto only could be produced by big-caliber guns. Such progress could first of all be utilised in siege guns, the weight of which was limited through the condition to which they were subject as regards transportability. All direct-firing guns could fire with a flatter trajectory in consequence of the higher setional density of the projectile due to its greater weight. The weight of the 15-cm shell rose for instance from 27·5 to 51 kilogrammes and its sectional density consequently from 156 of to 289 grammes per square centimeter. The increased cavity of the projectile afforded room for a greater bursting charge, and the bursting effect was raised accordingly, which was of importance particularly for guns with a curved trajectory. Furthermore, as the projectile now could be driven home right into the lands, up to the driving band, more room was afforded for the powder charge, so that the initial velocity could be raised without having to make the gun longer. On the other hand it was possible to shorten the gun if no increase of the powder charge was required, and when an increase of the length of the rifled part of the bore could be dispensed with. This was an advantage of which mortars and howitzers profited, which as a rule are supposed to have a short gun. The favourable results of the trials with shell between 3 and 5 calibers length gave rise to considerations as to the practibility of firing shells of 4 calibers in length against armour, and to experiments as to their effect on impact when fired at high velocities. The use of long shell opened prospects of a possibility to raise the ballistic effects for great guns both in respect of penetrating power and bursting effect. In order to gather experience on this point a 10-cm gun was built in 1876. On the results obtained with this gun, the principles were based for the further development of guns of all calibers, towards higher efficiency. The experience gained was for the first time put into practical use in winter 1878/79, in the construction of the 10·5 cm gun L/28·5. The efficiency of this gun caused quite a sensation during the great firing tests in August 1879 on the Meppen proving ground.

A few remarks may be made here on some gun constructions of the Krupp works during the period 1871 to 1887. Still during the war of 1870/71 Krupp constructed a 21-cm siege howitzer L/11·8 which, however, only was finished after the war in consequence of other more urgent work. This howitzer was intended as a breeching gun, its shell therefore, of 3 calibers length, was given a great bursting charge. The gun was placed on a wheel carriage, with riveted wrought-iron sides, the construction of which gave much useful information. The carriage was fitted with an elevating gear worked by a toothed arc. To check the recoil, it had a brake drum with a brake strap and cable. Such 21-cm howitzers have been delivered in considerable numbers to Belgium and Roumania. A 21-cm siege gun L/16·2, which was constructed at the same time and was exhibited in Vienna in 1873, proved more effective as a breeching gun, it was placed in an iron slide carriage, the chassis of which could be made transportable on wheels. A 15-cm siege gun on the hoop system was built according to indications given by the Experimental Artillery Committee and was adopted in Germany as Mark C/72. For the carriage of this Krupp for the first time adopted that shape of its sides, which were made of iron sheet, that had an elevated front part in which openings were left to diminish its weight, a shape which afterwards became characteristic for siege guns. From 1878 onward these carriage sides were pressed from one single piece of steel plate. In 1876 the 15-cm siege gun also was fitted with an hydraulic recoil brake.

In order to attack war ships by curved fire, Krupp constructed in 1872 a 28-cm coast defence and naval howitzer on the hoop system, of 11·4 calibers in length. The gun had quickly increasing twist, and fired shell of 2·8 calibers in length, weighing 216 kilogrammes. The difficulty of the construction of this howitzer lay in its mount, which had to permit firing at high elevations and yet could be traversed with great speed. This howitzer was exhibited in Vienna in 1873, and has, so it seems, shown the way to the use of curved-fire guns in coast defence. After having undergone many improvements, especially in respect of its mount, this 28-cm howitzer has become the principal weapon in the coast defence of Germany.

The experience gathered during the sieges that occured in the war 1870/71, brought about changes in the laying out of fortifications as regards sheltered posts and sheltered batteries, which, the same as the doctrines then in vogue as to the tactics of fortress warfare, attributed an important part to curved fire in the sieges of the future. This state of things caused Krupp to construct in 1879 a 15-cm siege mortar L/6·4 in a wheel carriage. If the Krupp works undertook comparatively late only the construction of a rifled mortar, this was partly due to the difficulty arising from the mode of forcing long shells with great bursting charges, the use of which only became possible when the front driving band could be dropped. Another difficulty was the construction of a carriage, easily enough to be transported with regard to its object, namely that of a siege gun, and which at the same time had to be fitted with a quick working laying gear. Something altogether new had to be found, because none of the carriages in use anywhere for rifled breech-loading mortars could be taken as a model. The problem in hand was in its main lines solved by taking the construction of the upper carriage of naval and coast-defence guns as a pattern. In building this carriage the elevating gear with toothed arc, as used for the 28-cm howitzer, was adopted with that modification that the toothed arc was placed under the gun tube; this device permitted elevations up to 60 degrees. Both the elevation and lateral training of the mortar, which could be moved about the central pivot, could be read from a fixed graduated arc. The mortar could be made transportable by placing an axle under its platform and by inserting a limber lever. This gun also was put to trials at the great firing tests in August 1879. Its excellent ballistic efficiency and other properties brought on numerous orders from different states. In May 1881, firing tests with shrapnels were carried out with this mortar; this was altogether the first time that shrapnel was fired from a curved-fire gun. After the model of this 15-cm mortar Krupp constructed one of 21-cm L/6·4, in 1881. To facilitate its use, Krupp had provided that its parts, the gun and carriage for one, and the platform for another, could be made transportable separately, although each of these parts were of light weight as compared with the 21-cm mortar in use elsewhere. Krupp's 21-cm mortar weighed 2015 kilogrammes, whereas the mortar used in Austria weighed 8035 kilogrammes, that used in Prussia, 5006 kilogrammes. The gun fired besides ordinary cast-iron shell L/2·8 with 4·8 kilogrammes bursting charge, also steel shell L/3·5 with 14·5 kilogrammes bursting charge, and steel shell L/6 with 48 kilogrammes bursting charge, composed of prismatic and fine-grained powder. Such shell was called torpedo shell after the instance of the Americans, who fired then from smooth-bore guns. The first firing tests with such shell at Meppen, on January 10th 1882, furnished the proof, that it was possible to fire such long shell with great accuracy of fire from mortars, without their turning over during the trajectory, a fact which had much been doubted. When high-explosive bursting charges came into use, this torpedo shell was superseded by the so-called "mine shell". From the 21-cm mortar a shrapnel also was fired with thin walls filled with 1700 lead balls weighing 26 grammes each, and provided with a rear bursting chamber. Such shrapnels were used in indirect fire to attack troops under shelter, say such that were placed in the courts of fortifications. This meant an important innovation in conjunction with the above mentioned use of the 15-cm mortar, because it had hitherto only been practice to fire shrapnel from direct-firing guns. Because of their long trajectory these shrapnels were fitted with time fuzes having two composition rings, and a double acting screw plug. As the burning time of 28 seconds of the usual fuzes was not sufficient for all the various cases in which the mortar was used, also fuzes of 40 seconds burning time were manufactured. The advances made in the building of fortifications caused Krupp to build a 24-cm garrison and siege mortar, transportable on wheels, after the pattern of the 21-cm mortar. Firing tests with this gun were commenced in August 1884 before a select committee of officers, and were likewise attended with good success. As for siege warfare in most instances a curved-fire gun of 15 centimeter caliber, to which attached the advantage of being easily transported, was sufficient, Krupp built, towards the end of 1879, a 15-cm siege howitzer L/12; its carriage had sides pressed out of steel plate of the typical form, a steel axle and an hydraulic recoil brake, in conjunction with recoil wedges to facilitate the running out of the gun into the firing position, and a double-screw elevating gear, permitting elevations up to 45 degrees. The gun tube, built on the jacket system had 18 grooves and a twist near the muzzle of 20 calibers. This howitzer was put to firing tests in February 1880.

The hydraulic recoil brake, which constituted so useful a part of the siege carriages, had first been technically developed as an essential element of naval and coast-defence mounts, and gradually took the place of the trail brake with compresser. The hydraulic brake originally had four orifices in the piston through which the liquid passed, and during the recoil was pressed with all the more energy, the higher the recoil energy was. This forcing action constituted its braking power which, however, with slow movements hardly came into effect. It was therefore not possible by means of this brake, to fix the gun at any point on the chassis, and it became necessary to use besides a compressor strap. Krupp tried to do away with this device by altering the arrangements of the hydraulic brake. The 26-cm gun in naval mounts, exposed in Vienna in 1873, was fitted with this new kind of brake which had a massive piston and a tube by which the two ends of the brake cylinder communicated, and in which was inserted a valve. Only when this valve was open could the piston be moved backwards or forwards, when it was closed, however, the gun stood immovable on the chassis. This arrangement implied a certain danger, arrising from the inattention of the servants, for the gun would be entirely ruined by a round being fired when the valve was closed. So Krupp returned to the old device of the piston with four orifices. An improvement much desirable in this arrangement was the possibility of regulating the brake pressure during recoil in such a manner that it was at any point equal to the braking resistance. This was of importance with respect to the resisting power of the material. In order to obtain such conditions the diameter of the orifices in the piston had to be decreased in a measure as the gun receded during recoil. A kind of regulation to this effect was obtained in 1874 by a valve brake with four valves and in 1876 by a simplified arrangement with one valve. These brakes regulated automatically the quantity of liquid passing through the orifices in accordance with the pressure acting at each point of the recoil. A further improvement was obtained in 1882 by the design called "expander brake". In this, the piston rod was made hollow and inside it a conical expander, the point of which was fixed in the bottom end of the brake cylinder, was so guided that it regulated by means of its changing cross section the quantity of the liquid passing alongside of it, during recoil or running out. One year later the rifled brake was designed, grooves were cut in the inside of the bore of the brake cylinder the depth of which varied, being greatest at the bottom end and least at the top end of the cylinder. The piston of the arrangement was massive and the openings for the passage of the liquid were formed by the grooves. This brake it still in use to day, but also the expander brake was improved upon in 1888, in this way that by a peculiar arrangement a valve inside the piston permitted to regulate the recoil, as well as to effect the motion backward and forward of the gun by means of water pressure.

The main lines of the design for naval mounts was settled in 1871. In a measure, however, as war ship building, which really only began after the war, developed, the design had to undergo many modifications, all the more so, because the German navy was getting more and more away and independent of English influence in designing war vessels, the building of which was henceforth entrusted to German ship yards. This change of things is due to General von Stosch who in 1872 became the first Lord of the Admiralty. Krupp had not neglected to study the institutions of the English war ships, but his desire was to adapt them to German circumstances and above all to German naval ordnance which differed in principle. The results were the numerous improvements that were gradually applied to the arrangements of naval mounts, and which were partly due to the authorithies, partly to Krupp, and which by common agreement were carried out in the Cast Steel Works. For small caliber guns, truck carriages were used at first that recoiled upon two wheels in front, and on the trail transom behind. The recoil was checked by a Brook cable, and then a Brook shaft with strap was used, which during recoil was stretched, and by its reaction made the gun to run out automatically. This arrangement did not prove practicable in the long run, and Krupp tried to replace the Brook shaft in 1872 by an hydraulic brake, but as he was not successful at the time, he used a sliding brake with an automatically working compressor, such carriages remained in use until the end of the 'eighties. The carriages on wheels offered facilities in case the port holes had to be changed. But for gun boats and small craft, still during the war, bow and stern guns were required firing over the bulwark and keeping a large zone under fire; for such purposes the truck carriages were of no use because their firing height was too small. Krupp therefore was given the order to design a mount suitable for such purposes. The outcome of this was a 15-cm slide carriage with central pivot, the chassis of this mount stood on four flanged wheels moving on a circular traversing rail, and to increase the rapidity of fire, it was given a marked slope upwards, to effect the automatic return to battery. The traversing gear at first consisted of a chain wheel, the chain of which was in gear with bolts fastened to the deck. But this proved cumbersome to the movements of the servants, so that the arrangements afterwards were replaced by a training gear comprising a wheel and toothed rack. The rack at first was fastened to the deck, then it was moved first to the foot, then to the pillar and eventually to the upper edge of the pivot stand, in the shape of a worm wheel which was in gear with the worm fastened to the chassis. About the middle of the 'eighties the chassis for such mounts was quite short and very high and ran on rails with a steep slope upwards, up which the small top carriage, carrying the gun, ran during firing a short way only, being checked by hydraulic brakes fitted on the two carriage sides. The recoil finished the gun ran out automatically. This arrangement permitted quick loading of small caliber guns which since 1883 besides had received a quick firing breech mechanism. The problem of constructing a carriage for a great firing height to fire over the bulwark was afterwards tried to be solved by Krupp in a different manner. The result was the so-called oscillating carriage constructed in 1878, the chief advantages of which were the need of little space and the facility of attendance. During recoil the carriage and gun swang backwards about a joint near its foot the movement being checked by an hydraulic brake, the return to battery was automatically effected by the gun's own weight. A number of these guns were ordered by the German Navy and for many years several 8·7-cm guns in oscillating carriages were put up on board the Imperial yacht "Hohenzollern", these guns had rich artistic decorations engraved on them. In 1874 Krupp was given the order to construct a suitable gun mount for the 17-cm guns that were to be placed in sheltered batteries on board the corvettes "Leipzig" and "Prinz Adalbert". The chassis of these mounts had to be made as short as possible in order to gain space for the movement of the attendants in the middle passage. This gave rise to the mount with a short chassis upon which the upper carriage recoiled by means of a wheel arranged at its back and supported by girders, the wheel running on deck. Such mounts were given to the guns of all the nine corvettes with decked battery of the German Fleet.

The turret mounts constructed in 1869 for 21-cm guns to be placed on the first German ironclad "Arminius" were very simple in design. The chassis of the two guns were placed immovable and parallel to each other in the revolving turret, which turned on circular conical rollers about a hollow pivot resting on deck, by means of which a portion of the energy of recoil was transferred to it. In its main lines this arrangement was adhered to, until in the 'nineties the armoured pit, which went right down to the protecting deck, was introduced. The embrasures had to be made very high so as to allow the gun to recoil even at the highest elevation but this largely diminished the protection of the armour, a drawback which one tried to avoid by constructing the revolving turrets for the armoured frigates of the "Preussen" class. The "Preussen" launched in 1873, was the first German ironclad that had been built on a German private ship yard, the Vulcan at Stettin. In the autumn 1871 Krupp was required by the Admiralty to built a carriage mount with minimum embrasures for two long 26-cm guns. In this design which was presented in 1872, the hydraulic brake with communicating tube was for the first time applied. It was, however, not used, as it was proposed to apply the arrangement invented by Scott in England which consisted in the possibility of varying the hight of the bearings for the trunnions and thus to reduce the openings of the embrasures. This arrangement was applied to the 26-cm mount, hydraulic pressure being used to alter the height of the bearing according to three different positions. About the middle of the 'seventies the first ships of the "Sachsen" class were put on the slips. Above the back portion of their side armour rose an armoured citadel of oblong section, and open above, and amidship an immovable armoured turret, having no roof either, of pear-shaped ground section, and resting on the armoured bulkhead connecting the front ends of the side armour. The guns placed in this turret and in the four corners of the citadel were to be 26-cm L/22, that fired "en barbette" over the walls of this armour so as to have a beaten zone as large as possible and a good outlook all round. The guns therefore were not protected in any way above. The four guns in the citadel were to be given pivot mounts and the two guns in the armour turret were to be placed on a turntable. For both of these arrangements Krupp had to present designs. As the beaten zone of the guns in the citadel had to lie within an angle about of 120 degrees, no centre pivot mounts were needed, which besides had not been used for such big calibers then. The pivot therefore was placed so far in front of the middle of the chassis that the gun, run out into battery, had its centre of gravity just above it. The advantage of this arrangement was so obtain a solid support of the chassis during fire, and also of the upper carriage with gun, during the motions of the ship when rolling. The mounts were fitted with hydraulic valve brakes, and a traversing gear comprising a wheel and toothed rack. The same arrangements were adopted for the mounts of the 30,5-cm guns L/22, for the armoured gun boats, the first of which, the 'Wespe', was launched about the middle of the year 1876.—The turntable supporting the two 26-cm guns in the fixed bow turret on board the 'Sachsen' were given the same arrangements as those applied to the turret mounts of the 'Preussen' class. The traversing of the turntable could be worked either by steam or by hand. These turret mounts also were fitted with the valve brake. Besides, the chassis got buffers composed of a column of Belleville discs, instead of the India rubber buffers hitherto in use and which were composed of India rubber discs alternating with iron ones. These buffers served to attenuate the shock of recoil of the upper carriage or that of its return to battery by their elasticity. The spring buffer proved so efficient that from the middle of 1877, it definitively took the place ot the India rubber buffer. Krupp was led afterwards to improve the design of the pivot mounts which had its pivot placed forward in front of the middle of the chassis from the following reasons: England had opened the epoch of small gun boats, by the building of the ‚Staunch' class, that carried in front one single cannon, a 9-inch. gun placed in a Montcrieff disappearing mount. These boats were intended for the coast defence and were given very small dimensions, as no importance was attached to their seaworthiness. The gun could only fire ahead in the direction of the keel line, so that lateral training had to be obtained by the stearing of the boat. It was for this reason that these boats were called "floating mounts"; Krupp raised strong objections to this arrangement, since he was of opinion that the gun's traversing arrangements must be entirely independent of the vessel, and yet must allow of keeping the whole horizon under fire. The outcome of such consideration was the central pivot chassis mount for a 30·5-cm gun, of the year 1877. The gun could be traversed together with the turntable which formed one with the chassis and its upper carriage, by means of four double-flanged wheels running on a circular rail, about a hollow central pivot which was fastened to the deck of the ship. This circular rail was placed on a likewise circular substructure, in order to obtain a great height of fire. The consequence of this elevated position of the turntable was a very great strain on the pivot, a drawback which was avoided in the next design of 1879 which provided the fastening of the traversing rail on the deck itself. The chassis on the contrary was given a greater height and a strong incline upwards to the rear, so as to ensure a short recoil, which at the same time was checked by an hydraulic brake, and an easy return to battery. So gradually the central pivot carriage was approaching its eventual form it took when ball bearings were applied. Ball bearings were first used in the guns of the coast-defence ships of the 'Siegfried' class, that were built in compliance with the Navy Bill of 1884. These vessels were armed each with three 24-cm guns L/35 in immovable armoured turrets or barbettes, and Krupp designed for them a central pivot mount, the upper portion of which could be traversed, not, as before, on wheels or rollers but on balls. This is the first use of balls in the building of gun mounts in the Krupp works, the idea of which perhaps may have been suggested by the English patent of Weickum taken out in 1873 for a ball bearing applied to turntables or perhaps by a sketch drawn by Alfred Krupp in the year 1876, for an armoured turret turning on a circular ball race, in which a gun with spherical muzzle was placed. The 24-cm central pivot mount with ball bearings was adopted for the ironclads of the 'Siegfried' class under the denomination of C/88. The substructure of the mount rested upon deck, and on its upper surface was fitted the ball bearings. In its centre a hollow pivot was arranged through which the piping for the hydraulic arrangements of the gun could pass. During traversing the balls were kept at certain fixed distances by means of a ring provided with holes. The turnable, protected by a cupola of steel plate, 30 millimeters thick, was clamped to the upper ring of the substructure, and thus was prevented from tilting during fire. The arrangement also helped to transfer the shock of recoil, which in the main had to be resisted by the pivot, also to the deck. The recoil of the upper carriage which ran up backward on the steep inclined chassis, was checked by hydraulic brakes attached to the sides of the mount. The arrangement for hoisting the ammunition were still placed outside the substructure, the ammunition being taken up to the gun for loading inside the turret. Centre-pivot mounts for big calibers kept these main outlines of design until the adoption of cradle mounts in 1892. The first mount of this kind with ball bearings was built for a small caliber gun in 1887. It was a 6-cm quick firing gun L/40 mounted on a pivot stand. This cylindrical stand, made of riveted steel plates,—steel castings were only applied for these purposes towards the end of the 'nineties—had a ball bearing on its upper edge. On this was placed the chassis, a steel casting. Its bottom face clasped round the upper edge of the pivot stand, whereas its upper face was fitted with a sliding surface that had a steep slope upwards to the rear, for the upper carriage. The adoption of quick-firing guns had been instrumental in the design of these mounts which permitted to lay the gun quicker. It was to the same purpose, that a seat was fitted to the chassis, on which the pointer could remain seated, when he was working the traversing gear, all the time keeping his eye on the aim. Together with the application of arrangements for quick-fire to bigger guns, the new gun mount design was also developed by degrees for these, and could in 1890 be used for 15-cm guns.

The Krupp works had there important share in all the improvements mentioned above. Even the beginning of many later innovations may be traced to the time before the death of Alfred Krupp. He has not himself lived to see the revolutionising adoption of cradle mounts, but he has almost anticipated this invention in his spring pivot gun. The naval gun mount with pivot fork resting on a supporting column, which was hailed as such an enormous improvement towards the end of the last century was a revival, more or less, of the pivot invented by Alfred Krupp twenty years before, as applied to his pivot gun. It was indeed given a new form which it has since preserved. The origin of the Krupp pivot gun is the following. The central-pivot chassis mount of 1877, designed for a 30·5-cm gun for gun boats had this drawback, that, when traversed, it required the use of much force, to reduce which a gearing might have been used, which again would have made the traversing movement too slow. During the deliberations as to how this drawback might be overcome, Alfred Krupp hit in 1878 upon the idea which gave existence to the pivot gun boat, named thus from a pivot gun with which it was supposed to be armed. In those days England's example gave raise to a lively discussion in all navies, of the question, whether it was not more useful and advantageous to build a large number of small craft, armed only with one single gun of big caliber, to fight the big and very expensive line-of-battle ships. Such ironclads, it was said, offered a large surface for the hostile gun easy to hit, and might be destroyed by one single torpedo well aimed. Alfred Krupp was a partisan of this opinion, and his interest, which at first only was turned to the gun, soon also was extended to the boat, both of which be endeavoured to develop technically as one unit. Pivot gun and boat ought to be made to suit their common purpose, so he thought. The trials therefore set on foot by him, extended just as much to the arrangements of the boat as to the gun and its peculiar mount. The peculiarity of the pivot gun was, that the gun was placed with its trunnions in a mounting, which formed the head of a column-shaped pivot forming one body with it. The gun therefore could not recoil; with its lower spherical end this pivot column rested in a step-bearing, and was kept in its vertical position by means of a neck journal arranged underneath the mount on the deck of the ship. The latter therefore had to stand the entire shock of recoil, there being no elastic medium to alleviate the shock, the whole construction of the ship was thus exposed to very severe strains; it had therefore to be built very strong, but naval architecture was not so highly developed yet. To elucidate all these matters, especially the practicability of the pivot gun, Krupp had placed an order with the Vulcan at Stettin, in 1880, for a pivot-gun boat 15·25 meters long, 3·36 meters wide and having a draught of 1·3 meter. It was armed with a 8·7-cm pivot gun, and eventually brought to the harbour of the Krupp Johanneshütte near Duisburg. The firing tests gave rise to many interesting new points, among which the necessity to alleviate the shock of recoil by using an elastic medium stood foremost. For this purpose, an 8-cm gun tube without trunnions was placed in a sleeve provided with trunnions, the whole resting in a pivot fork. Here we have the origin of the present-day cradle. In front of the sleeve, a column of cup springs, and behind it, a couple of these springs was passed over the gun tube, the former were compressed by the firing shock and permitted a recoil of the gun of one caliber length. They also by their reaction pushed the gun back into the firing position; when running out the springs at the back of the sleeve acted as elastic buffers. It was stated by measurements that the energy of recoil was largely diminished as compared with the former rigid system. In consequence of this, in 1882, a 10·7-cm spring pivot gun was placed into the boat originally destined for a 8·7-cm gun. In order to obviate the difficulty of making the required very big cup springs of sufficient resistance, trials were made towards the end of 1882 with spiral springs of square section or that of a flat oblong. The latter shape was applied in order to obtain the necessary stroke of compression without impairing the elasticity of the system, for "the single spires may not touch one another", so Alfred Krupp wrote. It is well known that the recuperator spring of flat section has 20 years later been adopted for good and all at the Cast Steel Works. The possibility of rapid attendance or quick fire was to Krupp the chief advantage that was attached to the pivot gun, as compared with all other gun mount designs, then applied. The working of the elevating gear was facilitated by the fact that the gun tube had no preponderance at the breech, and that the traversing operation found comparatively little friction. The armoured shield, carried by the gun, efficiently protected the servants against hostile fire, much better than they were by the disappearing mounts or the guns placed on the turntables inside the barbette turrets, as were in use on board English boats. In spite of all these advantages Krupp never received any order for the pivot gun boats, which partly may be attributed to the change of ideas that had intervened as to the fighting qualities of small gun boats, wanting in seaworthiness, partly also by the general advancement that the building of naval mounts had undergone. The central pivot mount with ball bearing and a short recoil transferred the shock of the recoil energy to the deck of the ship in a much less destructive manner, than the pivot gun, and this was the final reason, in the face of the quick rise of the ballistic power of guns about that time.

Krupp also considered the pivot gun well suited for coast defence, and by way of trial had emplacements carried out for such. A pit was arranged for the pivot in a foundation lined with iron sheet, and made of brickwork or concrete. The upper face of this foundation bore the platform on which stood the men attending the gun, the bottom of the pit had a step bearing for the pivot column, while its top aperture was closed by some iron structure, in which was fitted the neck journal for the pivot column. This neck bearing had to sustain the shock of recoil, and transferred it to the foundation work. The mount was protected by an armoured shield. The advantages of this arrangement were supposed to consist in a greater firing speed, in consequence of the easiness of motion for training the gun, and the absence of recoil. According to Krupp's idea it seemed particularly suited to pursue quick-going vessels and should therefore be put up at such points of coast fortifications whose task was to keep a large horizon under fire. Such coast pefence guns were shown under fire in the great trials at Meppen in 1879. The 8,7-cm gun L/50 No. 1 was placed in a pivot mount without recoil, No. 2 in a pivot mount of the oscillating system. After having given good results in the firing tests, a 15-cm gun without recoil was built and shown at the trials in 1882.

Also for the quick-firing gun system the way has been paved by Alfred Krupp. The first step in this direction dates very far back. In September 1873, the chief of the Admiralty at the time, General von Stosch wrote to Krupp that the Navy had no suitable weapon for the defence against torpedo boats. Small arms fire was ineffective, the small caliber guns, as well the 4-cm balloon guns from the war of 1870, that had been taken over by the Navy, fired too slowly, case shot, when fired from big calibers however only hit by chance; much more was to be expected from a gun firing cartridges in quick fire. The question of using Gatling guns of bigger caliber was much discussed in England at the time, but Stosch would not hear of aquiring that system for the German Navy because he said:—"It may imply the adoption of principles which were not in harmony with the gun system as developed in the German Navy, chiefly by Krupp's ingenious endeavours." He thought the gun in question ought to be a machine gun adapted to the German system, and the solution of this problem could not, he thought, offer any insurmountable difficulties for Krupp. But is soon proved that these difficulties were far greater than could be anticipated at the time, and after 30 years' work only, Krupp has by gradual improvement succeeded in solving the problem. Krupp's automatic guns of calibers ranging from 3·7 to 10·7 centimeters, of which the 8·8-cm L/35 was completed in 1906, are an absolute solution of the problem set in 1873 by Stosch, to design a machine gun in harmony with the general German gun system. Krupp set to work even in the autumn of 1873 to build a quick-fire gun of 4 centimeter caliber, with one barrel. One gun of this kind was fitted for quick fire by the use of five cartridges placed in a revolver drum, with the other gun, it was insured by means of a cylinder breech mechanism similar to that in practice for rifles. Neither of these weapons gave satisfaction as regards rapidity of fire. The filling of the drum of the revolver gun, or the exchange of a filled drum after the five rounds had been fired, took much time, just as much as the loading of single cartridges in the rifle gun. In this respect they were inferior to the Gatling gun with 10 barrels, or the Hotchkiss revolving gun with five barrels. The latter, the inventor of which had started his trials in 1870, had by degrees been very much improved. The Grusonwerk had acquired the licence for its manufacture, so that also the German Navy in 1878, when it became a very burning question to have a gun for the more effective defense against torpedo boats, also started trials with the Hotchkiss gun. This circumstance gave occasion to Stosch, to revert to his demand made in 1873, and to inquire, if now a gun of that kind could be offered for comparative tests. The Krupp works only could reply, that they had gone into the question at the time, but had not been successful, and therefore broken off the trials. They declared, however, their readiness, to resume the experiments. After the lapse of a year, the works gave in a report, saying that they had experimented a 4-cm repeating gun, and that they would shortly send in for trials a second specimen. This has never come about, since the experiments, that were in the meantime carried on with the 3·7-cm Hotchkiss revolving gun, led to he adoption of this weapon for the German Navy. Krupp's repeating gun built in 1879, was provided with a funnel holding four cartridges, by the turning of a handle on the right side, the mechnism for automatic loading, firing, and ejecting of the empty cartridge case was worked. All the three guns, the 4-cm revolving gun, the rifle gun and the repeating gun, are still preserved in the Museum of the works. The barrel of the former is 20 calibers long, has 18 grooves with a twist of L/40; the rifle gun is 30 calibers long, also has 18 grooves with a twist of L/45, the repeating gun 40 calibers long has 12 grooves and increasing twist from L/0 to L/55. Almost simultaneously with the repeating gun, Krupp built a fourth gun for the defence against torpedo boats, but it owned its origin to another circumstance. The Swedish captain Unge had designed a self-loading rifle and intended in 1878 to built for the Swedish navy a mitrailleuse for the defence against torpedo boats. The barrels required, of 1-inch English caliber, and also the steel projectiles, Unge wished to get from Krupp. In the course of these negociations Krupp promised to furnish mitrailleuses of that kind. So the works started to build a four-barrel mitrailleuse, with a caliber of 1 English inch, but according to their own design. The steel projectiles fitted with a copper forcing band weighed 235 grammes, the powder charge 50 grammes, and the whole cartridge 355 grammes. By moving forward and backward an horizontal lever, the mechanism was operated in such a way that at the forward movement, the barrels turned, and at the backward movement the uppermost barrel was fired while at the same time the cartridge cases of the others were successively ejected and the barrels reloaded. This mitrailleuse, which has remained a unique specimen, since no delivery was made to Unge, was exposed at Düsseldorf in 1880, and it is now kept in the Museum at the works. Although Krupp's experiments, to produce a one-barrel quick-firing gun as a defence against torpedo boats, had not the results expected by von Stosch, they were nevertheless far from fruitless. The trials involved afforded a most profitable series of studies, from which the conviction was reaped, that the problem in question could not be solved on the road hitherto pursued, but must be attacked from another quarter. The first question was to design a practicable quick-fire breech mechanism, after that an arrangement for quick loading. Besides, the circumstance had to be drawn into consideration that the resistance of torpedo boats had been much raised, by an increase of the side armour, and the addition of longitudinal and transversal bulkheads, so that a 4-cm caliber would soon prove insufficient. This at once settled the question of guns with several barrels, as unpracticable; the problem could only be continued on the ground of a single-tube gun. The modern development of quick fire guns was introduced on the grounds discovered by such deliberations. The cartridge cases used at the beginning of these experiments weer manufactured by riveting rolled-up envelopes of brass sheet to an iron base plate, fitted with a rim for the ejector. They were attended by drawbaks, the base was often torn off, also the envelope was insufficient in elasticity, and thereby caused hitches in the loading operation, all which things were only removed by Lorenz in Carlsruhe, who during the years 1878/79 succeeded in making 3·7-cm cartridge cases, from one piece of brass by punching and drawing. This removed the main obstacle for the adoption of the Hotchkiss revolver gun of the German Navy. Krupp at once saw what importance attached to the use of metal cartridge cases which contained all in one, projectile, powder charge and primer, and therefore especially could dispense with any kind of obturation. It was on the basis of the use of metal cartridge cases, that he designed a quick-fire breech mechanism, and he has adhered to these cases in all the improvements it underwent, even for the biggest calibers. The use of bigger calibers for quick-firing guns essentially depended on the progress made by Lorenz enabling him to make bigger cartridge cases. Krupp and Lorenz worked hand in hand, which lent much enhancement to progress. In 1880 already Lorenz could make cartridge cases for 5 (5·3-cm) guns of excellent quality, so that Krupp could recommend, in 1881, to the Russian Government the use of metal cartridge cases for 8·7 and 10·7-cm field guns which were supposed to be transformed into jacketed guns, as he was convinced that the manufacture of cartridge cases for big calibers also was beyond question. The first Krupp quick-fire breech mechanism of the year 1883 was a vertical block operated by a lever fitted in the lower part of the mechanism, it had a pin-fire percussion lock and a cartridge-case ejector, which had to be worked by a stroke of the hand. The design was improved in the next year for a 8·4-cm naval jacketted gun, the ejector of which worked automatically. The lateral operator lever, however, was only applied to the mechanism of 1885, when it received that form, which, in the main features, it has permanently retained. The experience with vertical sliding breech blocks led to the opinion that the limit for their application as regards the size of caliber, was about that of the field gun. This limit was defined by the weight of the block, which when dropping had to be upheld by counteraction, and in closing the breech had to be raised again. It seems that the idea of removing these difficulties by mechanical devices, say the setting of a spring by the weight of the dropping block, and the utilising of the same spring in lifting the block when disengaged, occured to no one, at the time, devices that are used now-a-days and have helped to raise the aforesaid limit to much bigger calibers. These limitations did not exist for the working of the horizontal breech wedge; it was to this system therefore that quick-firing devices were now applied; the result was the cylindro-prismatic quick-firing wedge C/87 for small and medium calibers. It was fitted with a percussion lock, the striker of which was set by an initial turn of the locking screw in opening the breech. It is worthy of remark that the ejector of the cartridge case, applied here for the first time, was then given that design which it has retained ever since for all the different forms through which the Krupp horizontal breech wedge has passed. The experiences of naval warfare were the first to call for the construction of quick-firing guns, the corresponding devices therefore were naturally first applied to naval ordnance. A further development of the system, more particularly its application to guns intended for use on land, does not begin until after 1887.

A sketch of Alfred Krupp's work, as far as it bears on the improvements of artillery, would be incomplete, if final mention were omitted of the armour-protected gun, which had his special interest during the later years of his life. When the Russian general von Todleben visited Alfred Krupp in 1857, and in conversation mentioned the order he had received to strengthen the fortifications of Cronstadt, Alfred Krupp at his request sketched out for him an armour composed of iron bars fitted into one another in the way of boards by mortise and tongue. It was to this sketch that Krupp returned in 1873, when, animated by the success Gruson had had with his chilled cast-iron armour during trials held at the Tegel proving ground, he resolved to take up himself also the problem of producing a gun armour for land fortifications, and selected the armour referred to. Endeavouring to make the aperture of the embrasure as small as possible, so as to give to both men and gun the greatest possible protection, he gave, in 1875, spherical shape to the muzzle of the gun which was so lodged in the armour, that it turned in it in the manner of a socket joint. The armour plate being thus immovably joined to the gun, it had to sustain the entire energy of the recoil shock. The leading idea in working out this system technically was complete protection and quick fire. Absolute protection had to be ensured by making the armour as resisting as possible; it first assumed the shape of a straight wall, afterwards that of a vault, obtained as a compound steel casting having a hard outer and a mild tenacious inner face. The muzzle was guarded by a shot-proof embrasure shutter, that was only lowered at the very moment of firing. The last form this armoured gun stand received, was composed of girders covered by rolled ingot-steel armour plates, both girders and plates being face-hardened. In order to raise the firing speed, the gun was so firmly placed on the mount moving on rollers, that its lateral training was not affected by firing, both this and the elevation could be read from graduated arcs. It was supposed to be possible in this way to displace the striking point of the projectile by some definite measure, laterally or in elevation, without having to aim. The construction described was not destined to meet with any practical application, because it was too little practicable from tactical points of view. Major Schumann has afterwards most splendidly succeeded in further developing the idea in his armoured gun mount, which took up the absence of recoil from Krupp's armoured gun, and the traversing motion about a center pivot from Krupp's pivot gun. Schumann's armoured gun constructions passed into the hands of Krupp together with the purchase of the Grusonwerk in 1893. In spite of the ill success that attended Alfred Krupp's endeavours in working out his armour-protected gun, it nevertheless bore fruit in the shape of new ideas of which other fields of action eventually profited. So for instance have the trials with ingot-steel and compound armour plates suggested to Alfred Krupp the plan of erecting an armour-plate mill. He was able only during his lifetime to sketch out the general points of view for the laying out of such shop, the practical execution of wich was reserved to his son and successor Friedrich Alfred Krupp.

During the period from 1871 to 1887 several opportunities were offered to the Krupp works to show at Universal Exhibitions—Vienna 1873, Philadelphia 1876, Sydney 1879—to a wide circle of interested people, what progress they had achieved in the field of ordnance manufacture. But in order to give evidence of them to professional men in particular, two comprehensive test firings were arranged at Meppen for an international meeting. Alfred Krupp wished to prove in a most convictive manner to those he had invited, to what efficiency he had carried his guns, and to engage his guests to compare them with the artillery in use in their respective countries. He had invitations sent out to a large number of governments asking them to send delegates to be present at a series of firing tests, which were to be carried out between the 5th and 8th of August 1879. The invitation was accepted by 18 different states that were represented by 97 officers of all ranks, of the navy and army. In the course of the tests, rounds were fired from all Krupp guns of recent construction, the calibers of which ranged from the small ones to that of 40 centimeters of the coast-defence gun. The development of artillery during the next years, especially the progress obtained by raising the length of the guns to 35 calibers, made it desirable to give another evidence of them to wider circles. A second important series of tests therefore was arranged at Meppen on the 29th and 30th of March 1882, which was attended by 42 invited, representing 13 states.

A few remarks may be added here on the 40-cm coast-defence gun L/25 mentioned in connection with the first series of firing tests in August 1879. Krupp had already begun in 1877 to build a 40-cm hooped gun. In doing so, he was giving way to a prevailing tendency to outdo one another in big calibers. Italy had armed the battleship 'Duilio', launched in 1876, with an Armstrong muzzle-loading gun of 45-cm caliber, and the battleship 'Italia' with an Armstrong breech-loading gun of 43-cm caliber. England followed with one of the same type of 41-cm caliber. So Krupp could not remain behind. The gun shown at Meppen had a length of 10 meters and weighed 72 tons; it fired a shell weighing 778 kilogrammes using a powder charge of 200 kilogrammes; with an initial velocity of 519 meters, it developed a muzzle energy of 10,685 meter tons. This ballistic result enduced the Italian government, whose delegates had been present at the tests, to place an order with Krupp for four 40-cm guns L/35, intended for the defence of the harbour of Spezia. The jacketted tube of this gun was 14 meters long and its weight was 121 tons, the breech block weighed 3760 kilogrammes; with a charge of brown powder C/82 of 384 kilogrammes the projectile weighing 1050 kilogrammes was given an initial velocity of 579 meters, which means a muzzle energy of 18,000 meter tons. This meant a proportion of 149 meter kilogrammes to 1 kilogramme of gunweight; this was an efficiency quotient which had not been attained anywhere else. A reserve gun had been begun at the same time, which eventually was given 42 centimeters caliber, and afterwards was exhibited at Chicago in 1893. After it returned from there, it was kept at Meppen, where it still is, and where it is occasionally used for firing tests. For a length of 14 meters, its weight was 122 tons, it was therefore the heaviest gun ever built at the Krupp works. The steel and armour-piercing shell it fired weighed from 1000 to 1100 kilogrammes, the steel shrapnel fired by it, contained 3400 bullets of 100 grammes each. With a charge of 410 kilogrammes of prismatic powder C/82 the 1000-kgs. shell developed 604 meters initial velocity and consequently 18,594 meter tons muzzle energy, by which it would have been able to pierce near the muzzle a wrought-iron armour plate 107·8 centimeters thick.

When Alfred Krupp died in 1887, forty years had elapsed since the first cast-steel gun had proceeded from the Krupp works. After that Krupp had to fight 12 more years before he could carry his idea of the cast-steel gun, till in 1859 the decisive change for the better came, by the Prussian order for breech-loading guns. It was Krupp's own country therefore this time that helped him to gain the victory. After that time a rapid rise set in, and within a few years more the works' productive capacity could be raised to an extraordinary degree. They had not only produced all manner of guns, but the manufacture had also been extended to all the other ordnance material, such as carriages and mounts, projectiles, limber and wagons. The importance of the Krupp works in ordnance manufacture, after they had succeeded in laying the foundation by enforcing the recognition of cast steel as the suitable metal for guns, their significance for the development of ordnance also in respect of gun design, have been described in the previous chapter. A few words more may be said here on the expansion of the works themselves. The number of men employed in the gun shops properly speaking, in the years 1885/87 ranged about the average of 3000. As a gun manufacturer Krupp had extended his "clientèle" to all parts of the globe, and there remained few states only, that had not temporarily or permanently been his customers. Germany, of course, was the foremost among them, from abroad important orders came from Austria-Hungary, Belgium, Bulgaria, Denmark, Greece, Holland, Italy, Portugal, Roumania, Russia, Sweden, Switzerland, Spain, Turkey, also from Egypt, China and Japan, Argentinia, Brazil and Chile. The orders comprised field, siege and coast-defence guns chiefly, less naval guns. Up to 1860 the works had delivered 100 guns, the first 1000 was exceded in 1863, the first 10,000 in 1874. Until the end of 1887 on the whole 24,576 guns had been ordered, out of which 10,666 were for the home countries, whereas 13,910 went abroad to 46 different states.

## THE CAST STEEL WORKS DURING THE LAST YEARS OF ALFRED KRUPP'S LIFE.

The economic circumstances already related explain how the evolution of the Cast Steel Works, looked at from the outside, suffered a severe reaction after 1875. Special causes joined with the general depression of trade to render Krupp's financial position very precarious. The repayment of the great loan weighed heavily on the balance sheet of the firm for many years. Enterprises which had been started before the crisis, such as the purchase and laying out of the proving grounds, had to be completed, for they had become vital questions to the Cast Steel Works; extensive work set on foot by Alfred Krupp to keep his concern going, and for the benefit of his workpeople, without any corresponding orders raised the current expenses. But both the reputation and the standing of the factory gained by this undaunted persistence in working, in comparison with other concerns which had submitted to the crisis in a kind of panic. The dismissal of workmen could be distributed over several years, so that its effect was brought within bearable limits. But as early as 1878, collieries and smelting works, and the Essen works in 1880, ceased turning off men, for a slow upward tendency was beginning to be felt. The orders for rails, chiefly from the United States of America, even assumed such dimensions, that from 1880 till 1882, the production of rails was the highest attained by the factory.

A great share in the leading position which Krupp kept, also after the crisis was over, was doubtless owing to the brilliant part the Cast Steel Works took in the various exhibitions of that otherwise slack time. The first great event of this kind after the Vienna International Exhibition of 1873, was the Philadelphia Exhibition, held by the Americans in 1876, to celebrate the centenary of the Declaration of Independence. Krupp like all the German industrialists, was at first but little disposed to take any share in it; especially as a revival of foreign orders was scarcely to be expected at that time of general depression in trade. He was only induced to change his mind—greatly by the persuasion of the Mining Councillor Wedding—from patriotic reasons, and he then arranged such a brilliant display of the firm's products at Philadelphia, that his exhibits formed the chief attraction of the big Machine Hall. By sending his son to Philadelphia, Krupp clearly showed the interest he took in the exhibition. The Krupp steamer, the 'Essen', was employed for the transport of the exhibits to Philadelphia, she carried at the same time the splendid exhibits of the Prussian Mining Institute, and freights for several private exhibitors, among others, for the Borsig works. The gun-making department of the Krupp factory was represented at the exhibition by seven guns, from the smallest to the largest caliber then made. The crucible-steel shaft for the German corvette 'Stosch' already mentioned, was among the more remarkable exhibits, as were also fracture and bending tests of railway and ship material, and the first railway wheel made on the newly invented coil system which had been shown at an exhibition. Krupp was also represented by Bessemer steel rails and rolled iron and steel plates, and the high opinion gained by his articles among American engineers and ironmasters no doubt contributed to procuring the large orders which were sent to the factory from the United States during the following years.—Krupp's participation in the Health and Life-saving Exhibition held in Brussels the same year was of quite a different kind. Here for the first time an opportunity was offered of showing an international public what Krupp had done in the field of social betterment, and the award of the highest distinction the jury had to give, proved that his achievements in this line were not less admired than in that of steel and weapon industry. Neither Krupp nor any German industrialist exhibited at the Paris Exhibition of 1878. But as a substitute he gave a great display of the progress his guns had made on the big proving ground at Meppen in the following year. The part Krupp took in the two Australian Exhibitions, at Sydney in 1879 and Melbourne in 1880, was not great, but it sufficed to secure a more extended recognition of Krupp's cast-steel products in these countries; in 1880 the Cast Steel Works made a brilliant show at the Düsseldorf Exhibition of Industry and Fine Arts. The

Krupp pavilion, near which a 40-cm gun was erected, formed here, as at Philadelphia, the great attraction of the industrial part of the exhibition. Numerous products of crucible and open-hearth steel, boiler plates, and other parts for boilers of extraordinary size, marine crank shafts of the heaviest description, one of which—placed at the disposal of the Exhibition by the Hamburg-American Steampacket Co.—had proved its durability by five years' service and 262,000 miles of travel; then there were heavy iron and steel forgings, notable for having been worked under the Haswell hydraulic press,—a process little practised at that time. Then steel castings of extraordinary size for machine and ship building, and all the various older Krupp products were there, to show the many-sidedness of the Cast Steel Works. Among the war material exhibited, a number of gun-mount parts—besides guns and projectiles,—attracted attention from having been worked under the hydraulic press. Alfred Krupp had a catalogue made of all these exhibits, to which was added a description of the state of armoured guns and pivot-gun boats. The catalogue was presented to the German Emperor, who showed his interest in the Krupp exhibition by visiting it accompanied by the Empress. The International Colonial and Commercial Exhibition at Amsterdam was the last event of this kind in which the factory took part during Alfred Krupp's lifetime. It showed here by a number of narrow gauge and colonial railways, and by the exhibition of light guns and other articles then regularly manufactured, to what an extent over-sea and colonial interests influenced the activity of the works.

In the meantime, the internal evolution of the Cast Steel Works had proceeded steadily, even if its visible enlargements had been restricted to modest limits between 1874 and 1887. Until the summer of 1875 some of the shops were kept well going by the constant work required for the re-armament of the German field artillery, and after that every nerve in the factory was strained by the need of working more economically than hitherto, and instead of discouragement and slackness, a fresh spirit of brisk activity spread through the works. The invention and working out of the welded disc wheel, the introduction of improved methods in the manufacture of rails and tyres, new plant for cheaper output, — —such as the English tyre-rolling mill,—the blooming rail mill, all belong to these years. New plant for remelting pig iron was erected at great expense in the Bessemer shop; but it meant a considerable cheapening in the production of Bessemer steel. Fundamental alterations were made in the plate-rolling work, the first plant of which dated back to the middle of the 'sixties. The low value of plates made of Bessemer steel as it was then produced, and the failure of the first experiments in making armour had checked its development for some time. But now that better sorts of ingot steel had been attained by the open-hearth process, the plate-rolling mill was entirely rebuilt, and after considerable enlargements, organised as a separate department:—it started work in 1876 with one thick-plate mill, and one fine-plate mill in 1877. In 1879, a still larger mill was added, with rolls of 3 meters useful length. So the factory was in a position to show the world, by its exhibits at Philadelphia and Düsseldorf, that it equalled French and English industry in the production of large boiler and ship plates. Except for slight alterations in their auxiliary appliances demanded by modern improvements, these three mills have kept on working unchanged till the present time. The internal evolution in the war-material department also advanced. The laying out of the new proving ground at Meppen, required vigorous work from 1876 till 1878. Nor did activity in building quite cease. New shops were put up for gun mounts and carriage building, as Krupp had to satisfy higher requirements especially in heavy mounts for coast-defence and naval guns. After cast-steel shells with hard points had been successfully made, a new projectile foundry was built in the southern quarter of the Cast Steel Works, in 1879/80.

Unchecked progress in metallurgical matters also could be noticed during this period at the factory. The revolutions in the production of ingot steel were occupying all iron works of any importance during the 'seventies. In especial, numerous experiments were made in changing the Bessemer process so as better to utilise the phosphoric ores which predominate in Europe. Certainly these attempts continued unsuccessful until the end of the 'seventies, because no sufficiently strong basic lining could be found for the removal of the phosphorus in the converter. This difficulty was only obviated by the discoveries of S. G. Thomas in 1879, and then the experiments closed brilliantly in a revolution of the whole iron industry. Attempts had been made, as early as 1876, at the Krupp works to attain this same end by modifying the open-hearth process, and they actually succeeded —before the invention of the Thomas-Gilchrist process—in getting a very pure ingot steel from highly phosphoric sorts of pig iron, by a basic open-hearth process, and at last a mild ingot iron was also obtained very low in carbon. After a long time of experimenting in Martin shop I, which was at that time the great laboratory of the Cast Steel Works for new metallurgical processes, a process was invented by Narjes and Bender, which was afterwards patented, for fusing phosphoric iron—such as was obtained in large quantities from Krupp ores—in cupola furnaces; then dephosphorising it in a hearth furnace lined with iron slag, ore or iron scales, under basic slag, and finally decarbonising it in a second acid open-hearth furnace by the action of oxide of iron. The so-called Krupp washing process was bought by many wellknown German, French and American iron works, and employed by them with good results. Krupp himself succeeded in producing very mild homogeneous open-hearth steel ingots of unusual size by this process, and at last in producing a metal which for mildness and low percentage of carbon was greatly superior even to the famous English mild steel. A communication of the firm dated July 1st 1878, lays of this product:—

"For some time a material called ingot iron has been successfully produced in our works, which combines, in a high degree, the distinctive properties of wrought iron, and yet does not possess its unavoidable defects caused by the necessary welding, especially in the manufacture of big forged-iron machinery. In its chemical composition it resembles the best wrought iron; for instance with a percentage of carbon of about 0·10, ingot iron is considerably superior to the former in its physical properties, as has been proved by the most thorough tensile tests. The absolute tensile strength of ingot iron amounts to about 38 to 42 kilogrammes per square millimeter in big forgings, in plates even to 40 to 48 kilogrammes with an elongation of about 25 per cent and a contraction to about 50 per cent of the original cross section of the test bar. These data are sufficient proof of the excellence of the ingot iron produced in our works, for use in all constructions for which forged iron has hitherto been employed. Therefore ingot iron is specially to be recommended for parts of ship building, such as shaftings and crank shafts, plates, stems and stern posts, anchors, &c., as well as for machinery of every description, rolled and forged bars of every shape and size."

During this time further, steel casting developed to a branch of peculiar importance,—mainly in consequence of the stimulus given to it by Alfred Krupp,—its foundations were laid in the 'sixties when the manufacture of cast-steel disc wheels was begun. Steel casting, the clever invention of Director Jacob Meyer, of the Bochum cast steel factory, at first met with Alfred Krupp's most determined opposition, for he saw in this product, which was also called cast steel a probable rival for his forged crucible steel. He cried down the Bochum cast-steel bells, (which in the 'fifties were their most successful product,) with passionate fervour, calling them a product of cast iron,—not of cast steel. But when at last he saw that his mistrust had led him too far, and that castings of steel might be quite reliable in certain cases, he changed his opinion, and left nothing untried, to overtake the Bochum works in this field, which his good raw materials soon enabled him to do. During the 'sixties and 'seventies Krupp and Bochum had been the most notable makers of steel disc wheels, and in order to prevent a detrimental lowering of prices, it was in this branch that the first convention of price was made between the two works. Soon after the erection of the first open-hearth shop, an attempt was made at Essen to cast disc wheels from open-hearth steel instead of from crucible steel; by degrees, frogs, crossings and such like parts for railways, then rolling mill and other machine parts were added; this new and cheaper process developed quickly to such an extent that the whole of the steel casting was moved into the open-hearth shop. There were, however, some great difficulties connected with the subject, which were not quite overcome for years. Thus from 1872 onwards, vigorous attempts were made to improve the quality of steel castings, the manufacture of the moulds, and the whole process of the work, while Alfred Krupp himself often gave the impulse to fresh efforts. Among other experiments, he tried casting in rising stream which had been so effective in the technic of chilled cast iron and which he had formerly tried himself in casting rolls. After the middle of the 'seventies he succeeded—by improving the material of the moulds—in getting large castings of open-hearth steel too, not of only great uniform texture, but also of pure, smooth surface. Towards the end of the 'seventies, bigger steel castings such as rolls with oblique teeth, toothed wheels, marine screws, stem and stern posts, and rudder frames, piston rods and other machine parts, &c. were manufactured for sale, while for the factory's own use, very heavy parts of presses, rolls for the rolling mills, crushing rolls, &c. were cast. In the first half of the 'eighties, the Cast Steel Works undoubtedly ranked among the best makers of steel castings, especially of heavy pieces. About 1886, Krupp began to make heavy and rather complicated parts of mounts for the biggest guns by this process. Finally in that year the Krupp firm effected the purchase of F. Asthöwer Co.'s steel works at Annen in Westphalia, the German work best known at the time for specialities in steel casting. The transfer of this enterprise to the firm was attended with important consequences for both sides, it was also the last important purchase made by Alfred Krupp. We will therefore give a brief description of the origin and development of the Annen steel works.

These works were established in 1870 by a small combine of partners, and they throve so well during the great rise in industry that the number of workmen was soon 170. Not only steel castings for workshops and railways were turned out, but also cast steel and forged cast-steel parts for machinery, and a considerable quantity of gun barrels. After the depression of 1874, a downward tendency was noticeable here too, and the insufficiency of the factory appliances, especially in the plant of the foundry with its reverberatory furnaces, became doubly perceptible. In 1876, one of the partners, Fritz Asthöwer took over the sole management of the work, and continued to manage it for the next ten years with growing success. The Asthöwer steel castings were distinguished for an extraordinary degree of mildness and tenacity, unknown at the time in the products of other works, and they were therefore universally admired and recognised. The revival of business in 1878,—chiefly through large orders from Russia,—made a number of necessary improvements possible, especially the erection of an open-hearth furnace of 5 tons capacity. Before this there were only a crucible-steel shop, a small forge and rolling mill, and one mechanical workshop. A second open-hearth furnace of 10 tons capacity was soon added, and thus the weight of the castings could be considerably increased. The splendid place the factory took at the Düsseldorf Exhibition of 1880 widened its circle of customers greatly, even English ship builders gave large orders for steel castings, such as screw blades, stem and stern posts, &c. In 1884, the manufacture of locomotive wheel centres was begun; these were first used with great success in England and then in Germany. In 1886, Asthöwer began to do very brisk business with the German ship yards in building and machine elements for home shipbuilding. There was a splendid outlook for the factory, but another great extension of the shops and plant was required, if full use were to be made of the opportunity, and that involved considerable financial outlay. Taking things from this point of view, the thought naturally occurred, whether it would not be best to put the works up for sale, especially as proposals of purchase had already been made to the owner. The Annen works had for some time enjoyed a very high reputation in England, through the large orders they had delivered there, and English capitalists showed a lively interest in acquiring the concern. Negotiations with an English company were in fact nearly concluded, when the Krupp firm stepped in and kept the factory in German hands by purchasing it in November 1886. The activity of the Annen works coincided in many points with that af the Cast Steel Works. The manufacture of gun-barrels, and the mild steel castings mentioned above meant a welcome and lucrative addition to Krupp products. The former firm F. Asthöwer & Co. was now transformed into Krupp Steel Works Annen, late F. Asthöwer & Co., and Asthöwer himself was appointed to a post in the management at Essen, where, from 1887 till 1896 he was a technical member of the Procura, (or Directorium), and helped greatly to promote the further development of steel-casting. The Annen works throve more rapidly than ever under the new conditions. The number of workmen at the time the factory changed hands was 275, the extent of the premises 5 hectares, the area built over, about 1 hectare. By 1911 the number employed had risen to over 1000, the area of the factory to 17 hectares and of the buildings to upwards of 4 hectares. The first change, which took the form of a great enlargement, was finished in 1888. It consisted mainly of the erection of big crucible and open-hearth furnaces for producer gas fuel. The manufacture of steel castings of basic steel was transferred from Essen to Annen. At this time the first orders for big steel castings for the German Navy were executed, *i. e.*, all the castings for the cruisers 'Wacht' and 'Jacht'. In 1889, important orders were received for the four big ironclads then building for the German Navy, and owing to the insufficiency of the plant at Annen, and the difficulty of transport thence, the biggest pieces were made at Essen. An order given at the same time for two million rifle barrels for the German Army was also handed over in part to Essen for execution. The production of rifle-barrels went on increasing, and forms a speciality of the Annen works, particularly since the introduction of a conical-spiral rolling process. The increasing orders for steel castings made it necessary to erect a number of new buildings at Annen, but the rapid evolution of the German steel industry from the beginning of the new century, rendered all these extensions inadequate, so that in 1906 a complete alteration, modernization, and enlargement was begun. In 1909 the rebuilding was finished and the efficiency of the Annen works was much strengthened.

It is obvious from the facts just related that the period between the commercial crisis and Alfred Krupp's death, compared to the previous rapid advance, showed a tendency to standstill; at least outwardly, for inwardly it was not the case. On the contrary, undaunted work, reorganisation in many departments, and great technical improvements gave occupation to the years of even the deepest commercial depression, and exercised a beneficial influence not only on the material side, and Alfred Krupp kept up the courage of his fellow-workers in the dull years that followed the crisis, by his deep sympathy with all that happened, his pecuniary unselfishness, and his incessant striving for progress. This was the more necessary, because he himself,—though his influence still made itself strongly felt on the whole,—retired personally more and more into the background. He came less and less frequently to the works, and even tried as much as possible to avoid hearing the verbal reports, by which his directors insisted on keeping him informed of the course of the various branches of business. Sometimes it was necessary for the Procura to represent to him very stringently that his withdrawal might be detrimental to the whole concern, so as to stir him to his former active participation in business. He wanted to assure himself by all means during his lifetime, that the works would proceed in the right way even without his presence. He had formed too firm a conviction that he could manage everything without interfering personally, by a system of rules and instructions, especially by the ordinances contained in the General Rules and Regulations. This confirmed his desire to secure co-adjutors of the best possible capabilities. The Procura had received valuable reinforcements by the entrance of Alfred Longsdon for technical management, and Meyer for commercial, but neither of these men could be or do just what was necessary in the administration at Essen, as one lived in London, the other in Berlin. In 1878 the Wurttemberg Councillor of the Board of Revenue Gussmann became a member of the Procura, and proved to be the right man to bring the long-desired order into the finances, and the internal service of the Cast Steel Works. In the following year, Privy Councillor Jencke, who after a short and brilliant career was then at the head of the Saxon State Railway Administration, was placed at the head of the management of the Cast Steel Works. He had been recommended to Alfred Krupp by the Postmaster General Stephan, and the Prussian Railway minister Maybach, as the most suitable man for the post; he possessed talents of the first order, and could represent the firm adequately. With the admission of F. A. Krupp into the Procura in 1882, the renewal of the managing body, which had been prosecuted with vigour for the last ten years, ceased for the time. But the more efficient the Procura became, the more Alfred Krupp believed he could now at length see the wish of his heart fulfilled, and be able to lay down the burden of current business. What he now pursued with unabated diligence were certain questions which claimed his interest as an engineer. By this means he still kept in close touch with some of the departments, while he gradually drifted further and further from the whole.

One of the subjects which engaged his attention for many years, and which may be mentioned more specifically on account of its importance, was the secure fastening of cast-steel tyres on locomotive wheels. Since the invention of the weldless tyre, this question so important for the safety of railway traffic, had never ceased to have a place in his mind. In locomotive and carriage building works, the cast-steel tyres were at first secured in a manner similar to that in use for iron- and puddled-steel tyres, that is they were shrunk on and then secured by driving a conical bolt through them. Krupp at once drew attention to the fact that this way of securing was unsuitable for cast-steel tyres, and that by riveting these bolts a dangerous tension was produced. Indeed the rare cases of crucible-steel tyres breaking could generally be traced back to this cause. Instead of bolts, Krupp used for a time screws which only partly penetrated the tyre, but he admitted himself that this way of securing them was insufficient, and in 1861, he had experiments made to fasten the tyre by slipping a mild steel ring sideways on to the rim of the wheel and hammering it down over the inner edge of the tyre. Here he anticipated by many years, an invention which was not made still 1879, the spring-ring fastening which is now in universal use. This protracted evolution was caused partly by the difficulties of the problem, partly by the state of the railways at the time; which after the brilliant engineering advance of the 'fifties, aimed more at extensions than improvements. It was only the augmented speed of the trains and the enormous increase of traffic after the Franco-German war, which brought the question of securer fastenings for tyres again prominently forward. Many attempts were made to find a fixing device, which even if the tyre burst, would hinder the several parts from flying off in all directions. Krupp thought this might be managed by making the edge of the tyre go beyond the rim of the wheel and hammering it down against it. Many a sheet of paper, covered with his large writing and sketches from his practised hand relating to this matter were sent from the Hügel to the factory during the 'seventies. In 1876 the Mansell fastening with clinching rings was adopted, but it was not permanently satisfactory. Krupp suggested an attempt to press in the circular grooves required for this purpose, by means of sharp edged small wheels, while the tyres were being rolled, his advice was:—"to begin the experiment with tin 3 inches in diameter.... to continue with copper on a small scale, that was how we always began with tyres and disc wheels". The following year, an old English patent, the Kaselowski securing by means of a zinc ring, cast into a groove, was also employed by Krupp, and kept in use on a limited scale for about ten years. In 1879, the Prussian Railway Administration made their famous experiments at Cassel, which proved that the so-called spring-ring fastening was the most reliable. Krupp adopted it at once, but without ceasing his own experiments in further improvements. In 1882, he even had a testing machine built, for his own use, after the model of the one used at Cassel, with which he made further tests. In 1883 successful attempts were made to weld cast-steel tyres directly on to coiled wheels, an indisputably ideal combination, but with this drawback, that to put new tyres on to such wheels, when they are worn out, is both difficult and costly. On this account, and also because of the great cost of production, the sale of such wheels was rather restricted, and the shrunk-on tyre has kept its supremacy till the present day. It may be mentioned that the Cast Steel Works, probably in consequence of the International Exhibition at Philadelphia, delivered some of the loose cast-steel tyres for the well known American paper wheels, and that such tyres were made in rather large quantities until 1892.

It must be admitted that the manufacture of rails as carried on at Essen from the middle of the 'seventies till the middle of the 'eigthies was—in spite of the many improvements adopted—in a rather backward state. The Krupp rail-rolling mill was, as is wellknown, one of the first built for the working up of Bessemer steel (1864). But this fact was in reality the cause of many defects, which became apparent by degrees as it worked, and were the more perceptible as the competition with rail-rolling mills, built later and fitted with modern appliances, grew keener. From the first, the repeated heating of the rail ingot for the first forging and rolling had raised the cost of working. A certain saving was effected by the erection of seven gas furnaces for heating the ingots, but the old process for stretching the ingots by forging remained in use until 1876, when a blooming mill was put up for rough rolling the ingots. The substitution of cupola furnaces for reverberatory furnaces for smelting pig iron in the Bessemer shop, which was carried out at great expense, benefited the production of rails by providing cheaper raw material. The number of charges could now be so increased, that henceforth one Bessemer shop sufficed, whereas two had been needed hitherto and a third had been planned. But in spite of these efforts, neither the Bessemer shop nor the manufacture of rails, could keep pace with the output of other more modernly fitted works; the rail-rolling mill was also under a disadvantage because the blooming mill was so far apart from the finishing mill, besides its deficiency in mechanical appliances, such as live rollers and lifting tables for handling the work, which other works possessed. A few improvements made later could not remedy these inherent defects. Real uniformity of proceeding from the production of the Bessemer steel to the finishing of the rail was lacking, on account of the age of the plant, and no improvements could be really adequate until the whole was rebuilt. Then there were other drawbacks. The great distance of the Krupp blast furnaces from Essen made it impossible to convey the pig iron directly from the tap to the converter, to refine and finish it at once in the Bessemer shop, as did other works built more recently, particularly the English works. The advantage of converting pig iron while still in a fluid state, was recognised so thoroughly at the beginning of the 'eighties that English steel works conveyed the iron for miles in casting ladles to the converters. It has already been mentioned that Krupp wished, from the first to have such a combination of work, and that he had seriously considered, if he should build blast furnaces at Essen. But there were such great obstacles in the way of this, especially the difficulty of transporting the ore, that this solution of the difficulty had been abandoned time after time. If modern plant for production en masse had been put up at Essen, the finished products would also have been subject to the unfavourable means of transport, and thus have been at a disadvantage compared to other iron works, for instance those on the Rhine. In the middle of the 'eighties these drawbacks were so greatly felt, during a temporary depression of trade, that the firm had to face the alternative of competing with other firms at a loss, or of quite giving up the manufacture of rails. In fact this branch of output had sunk from 125,000 tons in 1881/82, to 75,000 tons in 1885/86. The most obvious way out of the difficulty seemed to be the removal of the Bessemer work, and the whole manufacture of rails to the Johanneshütte, which was situated more favourably than any of the Krupp iron works, besides which it supplied about two-fifths of the Cast Steel Works' demand for pig iron. Alfred Krupp, too, approved of this solution in theory, and in the January of the year he died, it was resolved to work out a plan for the removal of this department, and for the kind of plant to be erected. However, as the plan was evolved, great difficulties appeared, and this—combined with the return of a better state of trade which raised the demand for and the price of rails—postponed the execution of the project for the time, and was ultimately the reason that the proposed smelting and steel works were built in quite a different place and on a very much larger scale. Of this we shall speak later on.

Alfred Krupp's withdraval from current business, which we have already mentioned, also extended to the artillery department during the last part of his life. Until the development and introduction of the German field gun C/73, he had always been in the van as a designer and encourager, but as the technic of gun making continued to develope he retired more and more. His directing hand was now only perceptible in certain questions of detail, such as:—the improvement of gun steel or the manufacture of jackets for heavy ordnance. But the more he withdrew from active life, the more he devoted himself to special problems relating to artillery, which he set himself and at which he worked, in spite, of many failures, with the self-absorption and perseverance which might be expected from a character steeled by many struggles. These studies were directed to armoured guns with spherical muzzle, pivot guns, double guns, pivot-gun boats, &c. His work at these–his own original ideas–was the joy of his life, and it was difficult to oppose him in any details. Some great principle lay at the root of all these projects, though its ingenious originator did not live to see it carried into effect; still these principles led to important innovations in other forms, or at least laid the foundation for future great achievements.

Among the problems which had remained unsolved in former years and which occupied Alfred Krupp again in his old age, was the manufacture of armour plate, which attracted him chiefly as far as it concerned armoured shelters. We have touched on the first unsuccessful attempts in this field; the solution of the problem was reserved for a time which Alfred Krupp was not to see, though he did live till the first successful results had been obtained. He followed the course of the experiments that were made with intense interest and constant advice, and he uttered many a word of counsel that helped towards success. The armour-plate experiments were resumed in the 'seventies because of the study of making armoured guns, for one reason, for another, because of the need of more resisting armour plates which were called for by chilled-iron and steel shell. At first attempts were made—at the Cast Steel Works and elsewhere—to obviate the increased penetrating power of projectiles by using forged iron armour plates of greater thickness; a number of plates of this description, made by Krupp, and fired between 1875 and 1877, showed extraordinary tenacity. One of these plates, 200 millimeters thick, which was fired in October 1877, is still in the Museum of the Cast Steel Works. At the same time plates of the milder Siemens-Martin ingot iron were cast and rolled by various processes, as experiments and then fired. Two of these plates of 70 and 75 millimeters thickness, which were fired in April and September 1877, are now in the Museum at the Cast Steel Works, to bear testimony to the splendid properties of this ingot iron. Alfred Krupp himself was quite opposed to the making of steel plates; this is comprehensible when we remember the state of the ingot-steel industry at that time; he uttered repeated warnings against "employing anything but the very mildest, purest iron". But the rapid advance in gun and projectile technic made it imperative to give the armour plate a great degree of hardness as well as tenacity. Iron armour plates, for example, in consequence of their want of hardness, were quite unable to enter into competition with Gruson chilled iron armour for land fortifications. After 1877, Alfred Krupp began experiments in using open-hearth steel, partly alone and partly in combination with forged iron, so as to compensate for its brittleness. The making of compound plates of an iron backplate, and an ingot-steel layer cast-on, had been begun shortly before in England.—In 1879 such compound plates were produced at the Krupp works by casting hard and mild open-hearth steel, also crucible steel—partly in cast-iron moulds—so as to obtain the hardest possible face; but in spite of the excellent resistance of some of the plates, these experiments did not lead to the desired result. The making of armour composed of bars, which Alfred Krupp believed to have a particularly high resistance, and with which he had been occupied for 20 or 30 years, was now tried with mild open-hearth steel, which was afterwards hardened in water or oil. In the 'eighties steel plates too were tested in a hardened state. For instance in 1884 two plates of the mildest open-hearth steel, 180 millimeters thick were fired; one of them had been annealed, the other hardened by quenching in water. The latter showed a considerably higher resistance than the former when fired. These and subsequent firings were so satisfactory that in the same year, the possibility of making very large plates, 27 ft. long, 52 in. broad and 18 in. thick, of rolled mild steel was considered, and the building of a rolling mill sufficiently large was suggested, Friedrich Alfred Krupp was actively engaged in all these experiments which not only interested him as the future owner of the factory, but also as a lover of science; his father, too, who like many others hoped they would bring about a great improvement in his armoured guns devoted great attention to these armour experiments. His questions and suggestions were poured forth in quantities, sometimes from Hügel, sometimes from Düsseldorf, where he spent much of his time during these years. These communications were sometimes as concise as a telegram, but more frequently they were written in full to the engineers engaged in the matter, to the manager of the proving ground, and sometimes to Pelz, the trusty manager of the forges, who in return had to send a detailed report of how the forging and welding had turned out, Krupp reiterated once and again, that it was of no use to attempt the impossible in resistance, but the attainable must be sought with decision. A resisting power, which could withstand hard shell from a caliber equal to half the thickness of the plate at an angle of incidence of 45 degrees was for him the first thing to be attempted, and to be attained without counting the cost. How to produce economically, when the technical difficulties were overcome, was a matter for future consideration. For the embrasure shutters for his armoured guns which had first been made of mild steel to obviate cracking, he recommended the use of a tough iron plate, on to which a steel layer was welded in the forge and subsequently hardened. Thereby he hoped to prevent the deformation of the armour under the impact of the projectile, and at the same time to retain its former tenacity. This was how Krupp started his experiments with compound armour plates. In 1885, the first large compound plate was made of a 5½ in. ingot-iron plate, and a 2 in. crucible-steel plate which had been hardened in water. These experiments were diligently continued during the next few years. Some under the hammer, some in the hydraulic press, some by rolling, these plates of rapidly increasing weight were produced from every imaginable combination of wrought iron, open-hearth steel and crucible steel. As early as 1886 compound plates of 300 millimeters thickness were rolled. At the same time the manufacture of plates and projectiles of chrome steel was started. For hardening the surface, Alfred Krupp recommended, instead of quenching in water or oil, a similar process which he had employed 50 years earlier for hardening his steel rolls; namely, plunging the surface into a strong current of water, from which was evolved the process of hardening first under a large sieve filled with water, and then under pressure, the latter process being the more effective. The structure of these plates proved excellent, both as to hardness and as to durability of welding, so that the problem undertaken could be considered as comparatively solved in 1886, and the erection of the armour-plate rolling mill could be definitely resolved on, though Alfred Krupp was not to live to see the execution of the plan. Meanwhile experiments in increasing the size of the plates were continued. In 1887 one 2·8 meters long, 1·3 meter broad and 120 millimeters thick was rolled, and fired with 15-cm chilled-iron shell. The fruits of these extensive experiments were of course not reaped till much later. But we must not refuse to acknowledge that Alfred Krupp led the way in this field, too, with the goal clearly before him, with perseverance and with a fine disregard of the outlay involved, and that his endeavours have been rewarded with great results. His attempts to cast armour plates of complicated shapes, which could not be produced by rolling and forging, and his plates hardened on one side, take the precedence of all similar attempts, they must be appraised the more highly in that they were undertaken with totally inadequate technical resources, and yet obtained results which were very considerable for that time.

# ALFRED KRUPP.

The name of Alfred Krupp is associated with the idea of unexampled industrial success And rightly:—the works which were left to him by his father in the most poverty-stricken condition, rose under his management to the brilliant position of a world-wide industry, and this eminence was no mere matter of luck. Even if the ultimate success was not his exclusive merit, even if, with his usual modesty, he once said:—"I had more luck than my father had," still he was for 60 long years the motive power of the progress, and the life and soul of the enterprise. He was in fact more. He not only possessed the iron endurance which sustained him in the hard struggle to reach the goal, but he had also in an unusual measure, the moral firmness to use every success only as a means for further development, as a step to higher attainments. His true greatness does not lie in his outward success, brilliant as that was:—what attracts posterity to him is, first and foremost, the heroic force of brain and character which kept his energy unbroken, and his courage undaunted, during the long years of battle with endless difficulties, and which when the turn for the better came, developed him and his work into one of the most remarkable phenomena in the world of engineering and industry.

Alfred Krupp's life, from his childhood to the brink of the grave, was incessant work. Till his 36th year, the hard school of his apprenticeship and his arduous journeys strengthened his natural gifts and developed them to the highest proficiency. For 20 or 30 years more, as sole owner of the works, he had to fight for every little success, while difficulties and cares often threatened to crush him. But this bitter struggle with obstacles and repulses was the fire that purified his character and steeled it for greatest strains. After the brilliant development of the works during the 'seventies, after the success of cast-steel guns in the war with France, Alfred Krupp was at the zenith of his life, at the summit of his fame. Later years added no new traits to his character or to his renown. He remained in his old age, what he had been in the prime of his life, and the struggles and battles which had gradually become the atmosphere in which he lived, did not cease after fame was won. He never ceased to strive after progress and improvement, to endeavour to strengthen the stately edifice he had raised, and to perfect the organisation and inner cohesion of the works. Till the close of his life he continued to be the great teacher of those who worked under him, always seeking to inspire the whole with his own spirit, so as to secure his work against the storms of the future. Very seldom has the founder of a great industrial enterprise impressed the stamp of his personality more thoroughly on his work. Twenty-five years have passed since this noble, successful life ended. The works have been greatly and rapidly extented, their aspect has been changed by the progress of technic, and owing to the general rise in German industry, the unique place which the Cast Steel Works has attained in Germany could not be maintained in its former extent. But one thing remains as it was:—the works still stand by the principles which their founder gave them, and we may confidently hope that this firm foundation will out-last many a change and chance of time.

Though Alfred Krupp's personality stands out so prominently from the ranks of his forefathers, it was closely linked with the past. It reminds us of a remark of Goethe's, that a family does not produce a great genius suddenly, but must pass through a series of progressing excellence till it produces its grandest fruit. So it is with Alfred Krupp; he stands like a mighty corner-stone at the end of several generations, through which the gradual growth of his personal qualities is easy to trace. The family had been settled in

Essen for centuries, and had attained a prominent place among their fellow-townsmen. By their business-like capabilities they had acquired wealth and authority. They had made and increased their fortune in trade; and as town clerks, guild masters, syndics, town councillors and mayors they had helped in the long struggle of the citizens to assert and increase their rights and privileges against the encroachments of the Abbey. The characteristics developed in this strife:—energy, perseverance, prudence and a clear insight into the state of the times, were unmistakably the qualities from which the success of later generations sprang, but no name among these old Krupps has been handed down to posterity as a leader or innovator. It was not till the latter half of the 18th century that Helene Amalie Ascherfeld, the second wife of Friedrich Jodocus Krupp, brought fresh life into the family, and a hitherto unknown spirit of enterprise. For more than fifty years, this woman directed the course of the family history, and neither the husband whom she lost early, nor her son, seem to have understood the spirit of their age as she did. There was, at the time, a tendency to greater activity in industry in Germany. England and France were illuminating guides for Germany along the path which led an exclusively agrarian country to the opening up of the forces contained in the coal and ore, which till then had slumbered in the soil, unused or but little worked. Iron works and foundries were rising, the first engineering works were being founded, coal mining had received a great impetus from the use of the steam engine. Helene Amalie Krupp brought into the family an insight into these new economic tendencies. The work and thrift of the old Krupps provided her with the means of following her bent in this direction, and she bequeathed to her children her energy and her promptitude of action in preparing the ground for new undertakings and seizing the right moment to act. The purchase of the Walkmühle, the taking over the Gutehoffnungshütte, the partnership with Dinnendahl, are all proofs of her love for commercial enterprise; and the first purchase of coal shares by the Krupp family was made in her time. She added small but remunerative branches to her own retail business, and after the death of her son, she placed her young grandson Friedrich in a new and wider field of action by employing him at the Gutehoffnungshütte. It matters little, however, whether it was her example or heredity which reproduced in Friedrich Krupp the best qualities of his grandmother, he possessed them and increased their effect by his sane, farseeing glance, which caught the future needs of the age, and selected from among them the one to which he devoted his life. Thus the Cast Steel Works were founded. But the inherent limitations of his character prevented him from bringing them to success. A stronger than he was necessary to complete the work to which the capable grandmother had unconsciously led the way, and of which the sanguine grandson had laid the foundation.

Alfred Krupp's remark that he had had better luck than his father is true in the highest sense, if we take it to apply to the happy combination of qualities which he inherited from his parents. Their characters were entirely different in many respects, even contrasts, the father, farseeing and of undaunted courage, quick to resolve, of great discernment in planning and inventing, the mother simple-minded but strong-willed, hard-working and conscientious, full of patience and unwearying activity. Their first-born son inherited the best of both their characters, and their good qualities happily blended, rose in him to genius and greatness. A friend of the Krupp's at that time describes the mother as the source of Alfred's mental gifts: he resembled her, too, in his features. The unfortunate result of Friedrich Krupp's work and his early death, which dimmed his image for posterity, make this utterance comprehensible. But it is too one-sided. It is in those very qualities in Alfred Krupp which impelled him to action, that we recognise the character of his father.

The son possessed to the full his father's daring and love of enterprise, his tendency to greatness of conception, his capacity for organising and directing, the brilliant imagination which grasped at once what could be made of a thing, and finally that liberal spirit which could stake the present for the future. These qualities had brought ruin on the father, but they were not so dangerous for the son, checked and controlled as they were, by the strong traits which he owed to his mother, by his constancy, his love of order, and his steady application to work. The impulsiveness of his character was bridled and balanced by a cautious prudence, which enabled him to see things in the proper light, in fact, to look before he leapt. Perseverance and patience in the execution of his plans, a highly developed sense of order and of detail, a lofty sense of duty, which he had the power of inculcating in his workmen, these and other excellent qualities, we recognise as his inheritance from his mother. To these qualities, mixed with the good common sense and coolheadedness of his ancestors, Alfred Krupp no doubt chiefly owed his success, especially in his early years, and by these qualities he rose to real greatness. But the nearer he drew to the goal and the greater his work became, the more the rich qualities he had inherited from his father developed.

Alfred Krupp's birth took place during the hopeful time when the Cast Steel Works were founded. The parents, in the bloom of their youth and strength, welcomed the birth of their first-born the more joyfully, because it coincided with the first successful attempts which seemed to justify the most sanguine expectations. At his baptism the boy received the name of Alfried, which had been borne by the founder of the nunnery of Essen, Bishop Alfried. By this name he is entered in the parish register of the Reformed Church at Essen, and by it he was called at home and at school. But later,—apparently after his first journey to England in 1839,—he ceased to use it, calling and signing himself Alfred Krupp. The brothers von Kechel, by whose help his father hoped to realise the great dream of his undertaking, were his godfathers. But how differently did the future turn out:—Instead of quick success, came disappointment, and bitter years of fruitless work, and when the boy was in his teens, care and want haunted his father's house. Then they left the town and moved to the poor little house outside the walls, which now stands in the midst of the surging life of the works, bearing witness to their modest beginning. Then came the years of his father's last illness, when he left the grammar school by his father's wish in the spring of 1826, at the age of fourteen; he had then reached the fourth form. He had been by no means a model pupil, but he had been a clear thinker, and his school-fellows used to admire his gift of observation and his talent for drawing. Friedrich Krupp's original intention had been to let his son have a thorough mechanical training in the workshops of his friend Noelle, who had been for many years the manager of the Düsseldorf Mint. His frequent illnesses, however, compelled him to abandon this plan, and to keep his son at home to look after the works. So Alfred, while still a boy, entered on life, and replaced his father in the management of the business, learning at the same time by word of mouth in the smelting shop and the forge, the rudiments of the trade which was to be the means of livelihood for himself and his family. In the autumn, his father died, and the widow, trusting in the industry and energy of her eldest son, ventured to try and save her husband's creation from ruin. Then followed long years of bitter struggle for existence, during which the young manager of the works was burdened with almost super-human work. He divided his time between superintending and doing practical work, between the foundry and the distant hammer works, between correspondence and journeys in the neighbourhood to collect and deliver orders, and between planning, calculating and drafting in his poor little attic, where as he himself says:—"I worked and watched hundreds of nights, in feverish, anxious dread of the unknown, uncertain future." And how often, after his day's work, did he sit and study there, with a conscientious desire to make good what the pressure of poverty had prevented school from doing for his own education and that of his younger brothers. He persevered till he had attained what he needed, and even under this mental strain never lost his innate love of fun and sense of humour. But during these years his health suffered, and the effects of this overwork lasted as long as his life. "From my 14th year," he writes later, "I had the anxieties of the father of a family. I worked all day, and at night I worried over the difficulties that encompassed me. And while working as I did, sometimes all night long, I lived only on potatoes, coffee, and bread and butter, without meat, with the cares of the father of a family upon me, and for 25 years I held out, till, as my circumstances gradually improved, I could lead a more tolerable life." And while his health was impaired by the disproportion between rest and over-exertion, work and food, so his natural cheerfulness suffered from the pressure of care and responsibilty, and his character took a tinge of precocious reserve, dignity and sententiousness, which never left him. Thus Alfred Krupp's youth passed in his little family circle, amid work and self-denial, but still with the satisfaction arising from a sense of duties fulfilled, and the conciousness of making his way in the world by his own unaided efforts. His innate love of hospitality was limited by his narrow circumstances, but he made plenty of friends among young men of his own age, and many of these youthful friendships were only ended by death. At home, even after the initial difficulties of his work had been overcome, he devoted every spare moment to quiet thoughts and plans for the future; still these years of unintermittent activity were by no means monotonous, nor did they lack stimulating influences. The interests of the works were very dear to his heart, and his quiet domestic occupations were varied and enlivened by frequent business journeys, which sometimes lasted for months. The years between 1838 and 1843 were spent more abroad than at home, chiefly in France, England and Austria. These journeys greatly contribruted to ripening his judgement and developing his abilities. When he was at a distance from the works, he commanded a better view of them, and directed their management by advice and injunctions which bear most remarkable testimony to his activity in those early times. On these journeys too, he acquired the readiness of address, and the frank manner with persons of all ranks, which distinguished him in later life. His natural charm and dignity, his gentlemanly self-possession and his fascinating amiability were of great use to him. A German diplomatist with whom he made friends at this time in London writes:—"We nicknamed him the Baron; he was quite young, tall and slender, looked very delicate, but handsome and interesting, and he was a perfect gentleman." He acquired foreign languages very rapidly while he was abroad. French he learned in Paris, where he carefully avoided German society, spending his evenings very frequently at the theatre. He learnt the rudiments of English in the house of Theodor Sölling, his parents' friends, and by associating exclusively with English people during his stay in England, acquired such a thorough knowledge of it, that he spoke it as fluently as he did his native language. Later on in life, when his health rendered it necessary for him to go to Italy, he took up the study of Italian. On his business journeys his uncertain health gave him a good deal of trouble. He was so tall and narrow-chested that he used to joke about himself as a "fasting man", a "whip handle" and a "note of exclamation;" his lungs were delicate, he suffered from continual headache, and a weak stomach, and attacks of this kind sometimes confined him to bed for days, after the long sitting and writing which his thorough and detailed reports of his business journeys necessitated. He had learnt to ride when quite a child, as he had often taken little castings from his father's works to the Walkmühle, and he always found horse exercise the best means of improving his health. He rode regularly, and from the 'fifties, when his means permitted it, he became an enthusiastic horseman. "You will say I am becoming extravagant," he wrote to a friend, "perhaps I am. But this is my one and only indulgence. I really delight in horses, and perhaps I shall get another of the very best kind." In 1857, the first manège was built at the works; it was soon enlarged, and later on another was built at the Hügel on a larger scale. In the 'seventies, Krupp's stables were one of the sights of the neighbourhood, and the thoroughbreds which he gave to his friends, and others whom he delighted to honour, attained a certain celebrity. He continued to ride until the end of his life, and to this exercise he attributed the dignified, upright bearing which remained unchanged until his old age. Alfred Krupp lived the quiet life of his early years until his somewhat late marriage. He did not care to go into society, unless business affairs compelled him to go. His capacity for work astonished all those who worked with him; his occupations were only interrupted by a ride in the early morning or in the late evening; sometimes he spent a few hours in the town, playing skittles or billiards at the club. "This steady-going life suits me very well," he wrote to Sölling in the 'forties. Now and then on Sundays and holidays, the monotony was broken by a trip to Cologne, to see the Söllings, or to Metternich, where his intimate friends, the von Müllers lived. Towards the end of the 'forties, the little circle of friends consisting of the families of Krupp, von Müller, Sölling and Waldthausen and a few others, was enlarged by the arrival of the young Berlin industrial Gustav Jürst, whom Alfred Krupp came to love as a brother. As long as his mother lived, he did not set up housekeeping for himself. His frequent journeys, the burden of his many occupations, and the still doubtful state of the works were partly the reason that he remained single so long; partly too, the satisfaction he found in a quiet life with the mother he loved so dearly. He was, however, no misogynist, on the contrary, his prolonged bachelorhood seemed to him, according to his own statement, a hard lot. But is was a long time before fate showed him the woman to whom he felt himself drawn as quickly and imperiously as he considered necessary. It was not till some time after the death of his mother, that the long-desired event took place. During a visit to Cologne, and according to family tradition, at the theatre, he saw Bertha Eichhoff, the daughter of a Cologne customs inspector, and fell so deeply in love with her at first sight that all reflection and selection were at an end. He wrote to Jürst that he "had at last found the woman with whom, from the moment I first saw her, I felt sure I could be happier than I had ever imagined possible." Bertha Eichhoff was almost 20 years younger than Alfred Krupp, but she did not hesitate to bestow her love and her hand on the clever, refined man, whose name, even then, was mentioned with respect in industrial circles. The wedding took place in May 1853, and was celebrated at the works by a ball, and a torchlight procession, which the men made in honour of their beloved master. A series of happy years now began for the Cast Steel Works, only clouded now and then by Alfred Krupp's anxiety about the delicate health of his wife and his son Friedrich Alfred, who was born on February 14th 1854. Mrs. Krupp was a faithful helpmate to her husband, not only by her amiability and tact in entertaining his numerous guests, but also by her sympathy with all his anxieties and hopes, which he imparted more intimately to her than to any one. Before his marriage, Alfred Krupp had moved into a two-storied house which had been built beside the old home in 1844, while a new building had been erected for the offices. And now a cheerful circle of family friends from Essen and elsewhere, often assembled in the modest little room in the upper story of the new house. When the successes of the 'fifties enabled Alfred Krupp to overstep the limits of his extremely simple way of living, his first care was to provide a pleasanter home for his family. So he built the "Garden House" in the works, and surrounded it with pretty shrubberies and ponds, spacious and elegant enough to enable him to fulfil his social duties and obligations in a suitable manner. At the same time the so-called "Strangers' House" was built, for the reception of the many visitors who came from all countries to see the works, or to do business with the owner; this house was also in the works. There were already many distinguished persons among Krupp's guests. King William, who had visited the works as Prince of Prussia in 1853, came again in 1861, to see the hammer "Fritz"; again in 1865, and later on he paid the historical Sedan visit in 1877, and was Krupp's guest first in the Garden House, and afterwards at the Hügel. He also induced the Queen and the Crown Prince to go and see the works, which had excited his unbounded admiration. Krupp's hospitality and hearty kindness to his old friends and fellow workers never changed. Several times a week the circle of his employees, which in the 'sixties was still small, assembled in the Garden House, and amused themselves pleasantly with music, conversation and billiards. None of those who shared in these social evenings ever forgot the genial kindness and gaiety of the Krupps. But in spite of Krupp's love of simplicity, which never forsook him, he soon found himself compelled to extend the scale on which he lived. The great development of the works during the 'sixties, claimed all the available space inside the limits of the factory, and rendered residence in the Garden House less pleasant. So in 1864, Krupp bought an extensive, finely-wooded estate with a simple country house, on the northern slope of the pretty Ruhr valley, at an hour's distance from Essen. Here he spent part of every summer with his family. His health too, which had been much impaired by years of overwork, needed more care, and he spent several years in unwonted retirement from work, sometimes far from Essen, either in the South of Europe or in the mild climate of the south coast of England. After his return, the Garden House was given up; hygienic reasons, and especially the health of his son, who had always been delicate, made residence inside the works undesirable. There were other considerations too. The number of visitors of high rank, who were attracted by the fame of the Cast Steel Works and the increase of the manufacture of cannon, made it necessary to receive in a much grander style. So "Auf dem Hügel", the handsome mansion which is still the residence of the Krupp family, was built on a gentle eminence overlooking the Ruhr valley. In planning this new residence, Alfred Krupp displayed the generous profusion which always characterised his undertakings, and the principal building still fully suffices both in size and style for the present requirements of business hospitality. Here Alfred Krupp, when he was not obliged to absent himself on account of his health, spent the evening of his life, superintending his works from his lofty watch tower, and exercising the duties of hospitality to his friends, his employees, his business acquaintances, and the numerous visitors who came to pay their respects to him and to the works. He entertained all these people without any showy ostentation, and only made display when it was absolutely necessary. The wonderful success which had attended his lifework did not become widely known until Hügel was built, when reports spread of its brilliant circle of guests, and doubtless the opinion held by those at a distance of the "Gun King" was greatly influenced thereby. Those, however, who knew him intimately did not value him for his success, but for his lofty, upright, loyal character, which showed itself in his straight-forward and frank, but quiet and gentlemanly manner with people of the highest rank. It was that which first gained him the trust of his workmen and business friends, and it was always the most lasting impression which Krupp's visitors carried away from all the brilliant magnificence which surrounded him. This character, of so much depth, kindness and loyalty won him the affection of his King and Emperor, who during his frequent visits and audiences showed him a confidence bordering on friendship, a feeling which he—the Emperor—preserved unshaken, in spite of Krupp's detractors. Krupp was more than once summoned to the Emperor from abroad, to explain doubtful matters, or to give advice. This sometimes occasioned jealousy in influential quarters, but the Emperor's manner to him was never in the least influenced by this. On one of these occasions Alfred Krupp opened his heart to the Emperor in a long audience and asked at the close:—"Your Majesty has, I trust, no more doubts?" The Emperor replied "I never had the slightest doubt of you." The Crown Prince Friedrich Wilhelm too, who accompanied the King on his visit to Essen in 1861, granted his lasting favour to the works and the Krupp family. He repeated his visit, and arranged for that of the Shah of Persia; many other Princes of the Royal House, numerous Princes of the German Federation, the King of Roumania, the Emperor of Brazil (who was Krupp's guest several times after 1871), the Princes of Sweden, Spain and many others visited the works and were entertained at the hospitable house Auf dem Hügel. Among the influential men at the Prussian Court who early recognised Krupp's works, and the importance of his aims, and who gave him their assistance in difficulties, we may mention Alexander von Humboldt in the 'fifties, and afterwards the Prince Minister Carl Anton von Hohenzollern. General Stosch and General Voigts-Rhetz often helped in matters concerning ordnance. Voigts-Rhetz, who was, as Krupp said "a model of uprightness, intelligence and kindness", kept up a constant correspondence with him from 1860 till his death, he was one of the few, who, though much engaged with totally different matters, always took a lively interest in Krupp's plans and improvements, and found leisure to study them in detail with admiration and sympathy. General von Stosch, the Chief Lord of the Admiralty also fully recognised how great a man Krupp was, and how original a genius. Their friendship was also a lasting one, and was never in the least disturbed by the radical difference of their opinions on technical matters. From the 'sixties onward, Krupp found a valuable supporter in Bismarck, who had paid his first visit in October 1864 to the Cast Steel Works on his way back from Biarritz and Paris, and whose interest in their founder was so warmly excited, that he called on Krupp in person the next time that he (Krupp) was in Berlin. Though Bismarck did not understand technical questions, and though he never became really intimate with Krupp, still he fully recognized the importance of the Cast Steel Works and their head, and took every opportunity of promoting an undertaking so beneficial to the welfare of the country. His statesmanlike eye saw the value of Krupp's industrial genius to German policital economics, and Alfred Krupp nearly always found the Minister President, afterwards the Imperial Chancellor, on his side, when questions relating to the manufacture of ordnance or the export of cast-steel products were under discussion. Obviously Bismarck saw in Krupp a kindred creative mind, whose farseeing, comprehensive enterprises seemed rash at times, even to such men as Roon and Moltke. A remark made by Bismarck to some friends on the occasion of his first visit to the works:—"When I consider a thing right and possible, I try to carry it out, even if the most cautious and cleverest people think it impossible to be done," might have proceeded from Krupp himself, so completely did it represent his principles, and his strength of will.

Thus the number of Krupp's acquaintances gradually expanded into a brilliant circle of his most distinguished contemporaries, and the reception rooms at the Hügel, which had been built in anticipation of the future, fulfilled their object during his lifetime. But the change in his outer life did not influence his inward feelings. In his domestic circle, and to the members of his staff, who were often guests in his house, he always showed the same simple, genial heartiness, which the dignity of old age only rendered the more charming. But advancing years made large parties burdensome to him, and his weak health forced him to live rather more quietly than of old. The Landgerichts-Kammerpräsident Schorn gives us in his recollections a vivid picture of the life at the Hügel, where he was a frequent guest. "Friends and acquaintances," he says, "passed many a pleasant hour in the magnificently appointed house, to which a young, beautiful and thoroughly amiable woman gave a special charm and liveliness, while the frequent presence of foreign officers added to the interest, and gave a cosmopolitan character to the party. As the master of the house grew old and the inevitable weaknesses of age came upon him, the gaiety and bustle around him often became a little irksome to him, and he would retire to some quiet corner, and play dominoes or some other game with his intimate friends." He also gives us information about Krupp's personal appearance and bearing, which complete the description of his youth. "Born to be a ruler of men, there was something royal in his manners and bearing. The ruler could be heard when he gave his dignified orders to his house-steward. He looked the prince too, on great occasions, when his tall, upright figure appeared among his assembled guests, and welcomed them with a truly majestic cordiality. But as soon as he took his place at the head of the table, he laid his stateliness aside, and led the conversation without any formality or stiffness." In his latter years he loved to return in thought to the beginning of his life and work. He often dwelt, both in writing and conversation, on his technical experiences and his personal reminiscences, and he was specially fond of recalling the cares and limitations of his youth, which he held up as an encouragement to younger men to persevere under difficulties. He would often describe the time when he, scarcely more than a school-boy, took upon himself the burden of the head of the family, working hard all day and studying half the night. Sometimes he would ride to the old hammerworks at Altenessen and show his friends the dark, winding stair which he had so often climbed to his little attic, and the peartree under which he had so often sat and watched, till the miller up-stream had finished grinding and drawn the floodgate, so that the hammer could be set going again. He clung with filial piety to the little old cottage in the works, and when the house he had built beside it was pulled down in 1872, he decided that the original home should be left standing, unchanged in any respect, and that even the furniture of the rooms should be restored exactly as it used to be. "The cottage must be restored just as it used to be," he ordered. "Furniture, stairs, stoves, slating, pictures, wall-papers, wainscoting and panelling, all shall be exactly as they were in old times. Room A is to have one window as it formerly had, and all the shutters are to have a heart-shaped airhole. The cottage shall not be adapted to any business purpose. I desire that it shall be preserved as long as the works stand, and that my successors shall view this memorial as I do, with thankfulness and joy:—it is the origin of these great works. The house and its history may give courage and perseverance to those, who are daunted by the hardships of life, may it also warn everyone not to despise the day of small things, or to give way to a haughty spirit. When I am at the works, I make this cottage my head-quarters, I desire to be carried to my grave from this house."

* * *

Alfred Krupp is a striking example of the truth that even genius can only assert itself by hard work and patience, and that it only attains permanent success by the rough path of ceaseless endeavour. He himself considered diligence as the root of his success. "I have inherited the industry," he said, "with which my mother kept the household going." He went to work with unflagging zeal and no occupation was too insignificant for him. He turned his hand to anything and everything in the factory, wherever help was needed; he was procurist, correspondent, cashier, smith, smelter, cokebreaker, watchman at the cementing furnace, and many other things of various kinds. He was very thrifty of time. When his day's work was done, he sat over his plans in his attic till far into the night. He was just as untiring when he was travelling in his youth, he called on customers during the day, did his writing in the morning and evening, and generally took his night's rest in the carriage. He had a keen thirst for knowledge and always strove eagerly to acquire it, especially when without any of the necessary training he began his work. "One ought not to be ashamed," he would say, "to learn something from the stupidest lad who blows the bellows." He lived solely for his work, and often when he seemed to be doing nothing, he was in reality intensely occupied. The very workmen knew that:— "When Herr Krupp was sitting alone, he was generally hammering some scheme out." He once wrote: "Whole days go by sometimes, when one is turning a notion over and over in one's mind, one looks as if one were doing nothing, while the whole time, at meals or on horseback, one has only the one idea in one's head." He was always in the factory, and even when he had to leave the management to others for a time, he devoted incessant thought to it.

The love of work by which Alfred Krupp was actuated and which he valued in others, was no mere fussy, purposeless activity. An innate sense of order directed his work and showed him how to attain his ends by carefully considered means. It also taught him to recognise the value of the slightest progress, and not to overlook the work lying nearest to him, while he fixed his attention on the distant goal. So he completed what he did step by step, making sure of the future till he reached his object. He could not bear arbitrary departures from rules, and even if he were a little pedantic in this respect, the touch of pedantry was of immense help to him in his life's work. From his youth he had the gift of so dividing his own labour and that of others, that the best use was made of time. Later in life he devoted the most careful attention to regulating the management of the works, and the thorough supervision of all departments. He had quite a mania for tidiness too, even in trifles. Rubbish lying about, a broken window, a clock which did not keep time, always called forth a sharp rebuke. An instinctive feeling for consistency in all things taught him the significance of outward neatness for the internal orderliness of the works. In the same way he considered thrift as one of the key-stones of economical success. Not only the poverty of his youth, but also the simplicity of his tastes, taught him this virtue. He recognised the value of everything, however small, and strove to utilise it. And thrift was more to him than a virtue taught by necessity. He regulated his outlay according to its object, and where such outlay was not really justified, he called it extravagance, of which he had a perfect horror. Still he was neither closefisted or mean about money. When after mature consideration he undertook a thing which required and justified expenditure, he was quite ready to make great sacrifices.

Alfred Krupp's zeal for work was united with reflexion. His mother had taught him to do everything thoughtfully. "Whatever you are doing, keep your eye on the end." His clear head kept him from acting rashly, a cool judgement and a practical perception of what was attainable, kept him from self deception and disappointment. Self-discipline and experience helped him to bridle his impetuosity, and he could be, at need, a masterly diplomatist. "Every truth that serves an end must be told frankly. But all needlessly irritating words should be avoided, when the end can be attained without wounding any one's vanity." Though he was by nature hot-tempered and outspoken, he could assume absolute calmness in difficult transactions and when making important decisions. His natural prudence and caution held him back from new undertakings, before he had thoroughly turned them over in his mind. But once he had begun a thing, he prosecuted his aim with unwearied steadiness and the greatest patience. Difficulties and failures could never turn him from the path he considered right, and the smallest step forward was for him the beginning of success. His tenacity of purpose under his early difficulties is shown in a letter written in 1839:—"I am as sick of Paris as of cold soup; I have paid at least 2500 visits to dirty people, often climbing to the fifth floor, now I shall get on better." Thus the requisite staying power was added to Krupp's diligence, and steady perseverance became one of his most striking qualities. He knew himself what he owed to it:—"You may think that the patience which has helped me so long will not forsake me now," he once wrote to his Berlin agent in a troublesome crisis. He went forward firmly and steadily, and while he gained step after step, and did not quail before obstacles, he never allowed new ideas to divert him from his path. He was a passed master in self-control, he avoided frittering his strength, concentrating it entirely on the great aim of his life; the prosperity of the works. All other interests were but secondary, and in this one-sidedness lay an important element of his greatness.

The growing extent of his enterprise called other traits of his character into play, and his prudence and constancy were balanced by his intense desire for progress. A longing to enlarge the field of his activity was noticeable. "A business in which I work, can hardly be too extensive, I should not feel at home in a small one." He was inspired by an immense love of enterprise, and he was always ready to stake what he had gained for new objects. "The whole thing is still in its infancy, it is only just beginning in the world," he said, in the 'forties, speaking of the new products of his works. To this daring we must add the energy which kept his courage unbroken under all difficulties. "Many a man would have feared and despaired ten times over. But I have always gone steadily on my way." Everything that Alfred Krupp planned was on such broad lines, that we can see plainly he was thinking not only of the present, but looking into the future and laying his plans for the time to come. This gift of creative imagination made his lofty aims clear to him, it was an illuminating power which guided his other talents and abilities along the way to their goal. Many of his creations still testify to the generosity of his conceptions; for instance the hammer "Fritz", the proving ground at Meppen, the workmen's dwellings erected in the 'seventies, and the building of the Hügel. He weighed such undertakings long and carefully, but when he was clear as to the end and the means necessary to it, he threw himself into the execution of the work with an iron will, a daring and a self-sacrifice that ventured everything for the future and often alarmed his fellow workers. Financial difficulties never deterred him from undertakings which he considered practicable, and necessary to the wellbeing of the factory. These were to him no more than obstacles which could be surmounted by a firm will. But his love of progress was always curbed by his cool judgement, and his enterprising spirit never betrayed him into unreasonable ventures. He could well write in 1871:—"I wish I could inspire others with my courage; it is not rashness, it is founded on conviction."

Krupp's self-confidence was based not merely on his far-sightedness, but also on the uprightness of his mind. "No man," says Carlyle, "can do anything at all, if he is not thoroughly in earnest about the doing of it, if he is not what I call an upright man." When Krupp was convinced of the utility of an object, he considered the prosecution of it as a moral obligation. Thence the desire to cultivate all that was good in himself, and the deep earnestness with which he devoted himself to what he did. To cultivate virtue and to do useful work, was a necessity for him his whole life long. His truthfulness and love of justice equalled his uprightness. He was never deceived by appearances. He always sought to have matters explained and set to rights, he would not have them glossed over. He did not consider himself infallible. "I make mistakes myself," he said, and "In the happy consciousness of my fallibility I shall always be grateful to any one who shows me my errors." If any one, however, dissented from his opinion, he expected to hear the reason; he could not admit any opposition which resulted "from indolence or want of elasticity". When he had been in the wrong he was quite ready to atone for it, because he only sought the good of the works. The cause was always more important to him than the person, and he was never deterred from necessary or useful actions by consideration for his own feelings or those of other people. He demanded the same candour from others; eye-service was hateful to him. Even when his manner was sharp and self-assured, he remained modest and simple of heart. He was devoid of personal ambition. He had no desire for titles or outward marks of distinction, and he refused the offer of being raised to the nobility. He also strictly forbade all ovations in the works. He was ambitious for his business, and for the recognition of the products of his Cast Steel Works, but he had no wish for personal publicity. He has recorded his thoughts about his own merit and success in an admirable letter:—"I am penetrated with the conviction that success ought to fill a man with no other feeling but gratitude. In his most arduous undertakings he has only followed the bent of his mind and made use of his talents, thereby finding perfect satisfaction for himself. Thankfulness for this is the only natural feeling. Ovations can but call up a blush." That which his contemporaries and posterity have considered as the greatness of his genius was for him only a necessary and natural following of the bent of his mind. We must also remember the philanthropic kindness which claimed so much of his time besides his active work. This was not a superficial, acquired quality, but was deeply rooted in his character. Even after his greatest successes, he never became cold or imperious, and till his death "a self-forgetting kindliness to all good men" remained deep rooted in his heart. This was the source of the good will with which he regarded all those who worked for him and with him, and which spurred him on to undertake his institutions for their welfare. It is here that we discover the ideals which really actuated Alfred Krupp. He was a thorough optimist in the best sense of the word. He believed in the progress and victory of the Good, he was convinced that "nothing exists,—no human work—that has not the capacity and the need of being perfected to all eternity". Thence came his desire for improvements, his constant struggle to raise and better the standard of his own actions. He wished to use his talents for the good of his country in general, and of his dependents in particular. Thence came his endeavours to make his country independent of all other countries in one important industrial product; nay more, to find a market in foreign countries for German products. Later in life, the lofty task of raising the defensive strength of Germany to the highest pitch fell to him and raised his conception of the importance of his work. His unshaken faith in the future of his cause, in the final victory of his cast steel rested on the consciousness of his own unselfish motives, and on the conviction that progress was universal. It was this consciousness, that kept him from yielding to doubt and hesitation even under the greatest difficulties, and that turned the scale in all his weighty decisions. Those around him caught something of this warmth, and even when they could not share his faith, his example gave them a powerful stimulus to do their utmost. He placed so high a value on faith in the future, that he used to say:—"To lose money is to lose little, to lose honour is to lose much, to lose courage is to lose all."

His moral code not only ruled his actions, but gave its stamp to his general conception of life. Work was to him not only a personal necessity, it was the moral basis of life altogether. He saw in work the only justification of gain, and gain was for him merely the starting point for fresh work, and the means of doing good. He refused to engage in any speculation or venture which depended on a lucky chance. "Lotteries are contrary to my principles", he once said, and at another time, "The proverb:—Nothing venture nothing win; was invented by folly for gamblers and adventurers, in short for everyone who does not act on mature consideration." He placed duty above everything, and the longer he lived the higher he placed the duty of promoting the welfare of his works. One outcome of this sense of duty was the strong feeling of responsibility which actuated him. He knew that he must one day give an account of the talents that had been entrusted to him, and he toiled unweariedly to school himself for his great task. He had just as full a sense of responsibility to those whom he employed, to those who had put themselves under his guidance; he was in solemn earnest when he said: "The end and aim of labour is the good of all." From his early manhood, reverence and gratitude for work faithfully done had been part and parcel of his being, and they never forsook him even when the works had developed to an enormous size.

Alfred Krupp's moral sensibility found its finest expression in his conception that the factory was a great corporate body which must provide, in the first place, for the welfare of all who belonged to it. This corporate body which he developed into a kind of state within a state, so organised as to provide impartially for all its nembers, could only rest on a moral foundation:—"Upright men, honest principles, justice and humanity must rule our actions, and then everything will go on improving." Union and moral conduct were for him the guarantee for contentment, and for a blessing on work. He called loyalty the foundation of everything. He considered it to be the strength of every human bond, the preliminary condition for all lasting success. He applied this principle to his business: —Loyalty to the works, devotion to duty were for him the keystones of the works, and acting himself strictly according to this principle he demanded the same self-surrender from every member of the community. But what he required of his fellow workers, he offered them in abundance by what he did for them, loyalty and gratitude for work faithfully performed:—"We only want loyal men, who are grateful to us in their hearts and lives for giving them their daily bread. We will treat them with kindness, and provide for them and their families." He liked his liberality to be looked on as a voluntary expression of thanks; he did not choose to be compelled to pay high wages, but preferred to give what was just of his own free will, and to add as much as he considered possible. If he discovered negligence in work, laziness or indifference, it was not the damage caused by them that vexed him, but the breach of faith, the offence against a recognized duty. Hence his indignation against the first movements of the Social Democrats during the 'seventies. He saw in their aspirations something more than a mere infraction of order and discipline. He was chiefly angered because the movement aimed at destroying all feelings of mutual confidence and loyalty in the workmen. He claimed full recognition for his own work, and faithful care of his men, he said so clearly:—"Every one knows that I have always respected workmen and work. But let every one know that a misinterpretation of my motives might possibly overturn my devotion to them, deep-rooted though it is." His clear conscience permitted him to use these words; and often afterwards he spoke to his men in "good plain German".

Such were the mental and moral characteristics which helped Alfred Krupp to build up his lifework. With all his greatness and versatility, his was not a contradictory character, it was clear and harmonious. This may be said in particular of him in the aspect best known to those who come after him:—the great industrialist. Here he was the great personality concentrated on his aims, forgetting himself in his work, and seeing in his fellow workers only instruments to be used in the great cause. All the qualities were combined in him which Lamprecht in his German History specifies as requisite for a great man of liberal enterprise. The keen critical perception, the quick enthusiasm for distant objects, the lofty impulsiveness, the powerful energy, and the clear will that teaches moderation. He was one of those natures in which activity and imagination, will and thought, cool reason and eager idealism, are most closely allied. The active will which impelled him onward, was controlled by qualities which kept him from overshooting the mark. His imagination and idealism were coupled with steadiness; his breadth of conception with a taste for detail, his versatility with a stern concentration of purpose; his love of enterprise with caution and foresight; his love of expenditure with economy. But he was never handicapped by these apparently so contradictory qualities, for each came into play, at the right time and in the right place. Krupp used his talents like a great general, who concentrates his forces, prepares to strike a great blow, and then, at the right moment, stakes everything to gain the supreme victory. He possessed an inflexible will, which surbordinated all the powers of his richly endowed mind to the great aim of his life, and strode onwards unhesitatingly when the moment called. No obstacles however great could weigh with him. "Attainment is a mere matter of will power." During the whole of his life he kept up a passionate struggle against opposition and hostility. His rallying word was:—"Now, onward with doubled and trebled energy!" In 1872 he wrote:—"Perhaps you will say that Alfred is possessed with the devil, and you will be quite right." He delighted in struggle and victory, even when he was an old man. His energy was perfectly controlled by a farseeing imagination which revealed the goal of his efforts to him, and by a capacity for enthusiasm which raised his activity to creative genius. No great and successful leaders of men have been without this touch of imagination and enthusiasm. Lastly, Alfred Krupp possessed the rare gift of imparting his own spirit to others, of animating those around him with the same love of work, the same devotion to the one great cause, as inspired him himself. This was the final condition for the success which so richly rewarded him and his work.

A character so strongly marked could not fail to mould his life and environment to its own form. In early youth fate settled his lot by giving him the task of rescuing his father's creation from ruin, and to this task he set with his whole energy and undivided attention. His gifts were marvellously manifold. He conquered one field after another as it opened before him, but he never gave his full attention to anything that did not promote his one great object, the Cast Steel Works. His whole powers belonged to the works, he looked on himself as their chief servant, their welfare, their needs had an all-imperative claim on him. From first to last his feeling for them was a warm personal feeling. "I look on the works," he writes in a early letter to a friend, "as a carefully brought-up child, which makes one happy by its good conduct. Why should not one devote as much time as possible to such a child?" The bond was never loosened, neither during the 'fifties, a time when there was a prevailing tendency to transform private enterprises into limited companies, when Sölling advised him to follow this lead so that he might be enabled to enlarge the works, nor in his latter years, when he was oppressed by the weight of business. He always continued to manage the works himself, responsible only to his own conscience. This absolute devotion to his works which excluded every other occupation sprang not alone from the identity of the creator with his work, but was the outcome of conscious moral reflexion. Alfred Krupp has been reproached with refusing to share in other interests, with taking no part in work for the public good. He was compared with his friend Harkort, who unselfishly devoted his work to the public service. The character of the two men presented, truly, a great contrast, which was once well described. "It was a curious sight to see these two famous men together in Harkort's little office. One had concentrated all his powers on one object, and had become the greatest industrialist in the world. The other had devoted his talents to the public weal, and had now in his old age to thank God that he was freed from the cares that had oppressed him all his life, yet had never turned him aside from his path." The two men, however, did not differ in the degree of unselfishness they displayed, but in the way in which they strove to reach their ideals. Alfred Krupp was among the first to realise the aims and objects which Harkort had indicated during the 'forties, such as Supply Stores, workmen's dwellings, benefit funds, &c. The one conceived the idea, the other carried it out. Krupp was no less conscious of his duty to the public weal than Harkort was, but he believed he was fulfilling it most perfectly, when he concentrated his social work on the needs of those he employed. Here a powerful instrument was placed in his hands to be wielded in the service of his fellow-men, for the improvement of home industry and the welfare of his workpeople. To mature, within these limits, the projects of philanthropy and of social culture, to give to his native land the best that could be manufactured, was in his eyes a loftier aim than to serve the public by political activity, or in any public office. He never hesitated to assert this. "The object of all our striving after knowledge is, and must be the furtherance of the reputation and profits of the works. Our task is not to work in the interests of science, or to run into expenses when such sacrifices are not seed for a future harvest." He was indeed convinced that he was a fellow-worker with those who were striving after the highest good of the human race, and since he saw his work in this light, he had every right to say:—"Then work brings a blessing, then work is worship." It is, in fact, impossible to appreciate Alfred Krupp, if we separate him from his work. It was the source from which he drew his strength, the field on which he displayed his untiring activity, and we can hardly say which aspect of this activity is the most important. His technical achievements were brilliant indeed, but they can only be rightly appreciated when his greatness as a man of business, the owner of a factory, as an organiser and teacher is measured. He was equally remarkable in all these aspects, and the talents necessary to each were blended to perfect harmony in his character, as he himself was at one with his works.

The first problems he had to face after his father's death were technical ones, and such questions, which were in perfect harmony with his inclination and his talents, continued to occupy him as long as he lived. The certain manufacture of cast steel of unvarying excellence was the first problem to be solved, the production of all the articles then used, to which it could be applied, the second, if he wished to fulfil the task that lay before him. These two problems turned his talents into the two fields, which he afterwards worked with such rich and varied results:—namely metallurgy and design. And yet he was absolutely without regular technical instruction. He said himself:—"Far from being well trained, I was just an ignorant lad, at the time I took over the management of the works." He never had the practical training in the workshops of an experienced mechanical engineer which had fallen to the lot of Borsig at Egells' works, or to Gruson at Borsig's & Wöhlert's.— He had not been trained as a chief artificer, or as a Royal engineer as Gross and Schumann had been, or his famous contemporary, Werner Siemens. It was solely by his own endeavours and in the limits of his own works that he became a metallurgist, designer and engineer. But without his truly marvellous mechanical genius he could never have raised the Cast Steel Works from their small beginning to their subsequent many-sided greatness, and render them famous by attaining perfection so quickly in every new branch of manufacture he undertook. We possess a number of sketch books and diaries, which give an idea of Krupp's development in technic between 1829 and 1838, from his 17th to his 26th year. This was the time of the hardest struggle to re-establish the works, and these books contain the results of those hundreds of sleepless nights which Krupp spent in his little attic "pondering how to attack and overcome his difficulties". These yellow old pages record the birth of every hope, every attempt to profit by every small success, every endeavour to surmount technical and pecuniary difficulties with the most modest resources, they show how many shattered hopes and fruitless experiments Alfred Krupp's instinctive experience as an ironmaster outlived, and from what petty tasks and beginnings his amazing talent for design developed.

Krupp's father had now and then manufactured cast steel of the best sort, but without any certainty of being able to reproduce it at will. It was Alfred who discovered the raw materials and perfected the processes, from the crucible to the fusing, which guaranteed lasting success. For many years he had no chemical analysis, no mechanical testings to help him, it was all a matter of experience, of a sure eye and an inflexible conscientiousness, qualities which Alfred Krupp knew how to instil into his assistants and workmen. As the domain in which cast steel could be used, widened, the demands on it rose, and here again the various kinds of steel suitable for the most different purposes had to be discovered and made adaptable by alterations in the component parts or in the process of melting, without the aid of science. Then came the manufacture of ingots of constantly increasing weights, which were cast first from hundreds of crucibles and then from more than a thousand—these were needed when cast steel came into use for rolls, axles and cannons—and here too Krupp proved himself a master in experience and in schooling his assistants. Success came at first slowly, but afterwards with amazing rapidity; thus we can understand that, however highly he valued scientific means, he always considered practice as the real root of success. In his old age he often maintained his own ideas, founded on the 50 years' experience of "an old practical workman", against the doubts of scientific criticism. As an iron founder he was not content to stop short at crucible steel. When he began to try the manufacture of heavy rolls in the 'thirties, he recognised the superiority of chilled cast iron and of certain steel alloys, and worked at the matter for some years with a certain measure of success. Then, as his range of work widened, it became necessary to produce brass and cast iron, and Krupp who till the 'fifties was the only experienced technician in the works, attacked the question without hesitation. He made his first bronze bearings out of old brewery boilers, and 1854, he set up his own iron foundry with a cupola furnace of an output of 18 hundredweights an hour. The manufacture of steel gave a special direction to this branch of production. Then Krupp's horizon as an iron founder widened with giant strides. Apparently at his instigation, steel puddling was introduced at the Lohe iron works, and soon after the big puddling furnaces were constructed in the Cast Steel Works, which henceforth supplanted the old cementing process. The manufacture of railway wheels led him to casting steel in moulds, and by tremendous efforts he raised his foundry to the level of the older works in this branch. On Bessemer's first appearance Krupp's keen eye recognised the future value of the process, and he boldly began to carry it out on a large scale. Gas fuel, the regenerator, the Siemens furnace, and every new improvement in foundry processes were placed at the service of the works soon after their invention. As soon as the Martin process was invented he began to test it practically, and after some years, undeterred by the great outlay it involved, he set up an extensive plant for it, so that he might keep his rank in the forefront of steel manufacturers. Again in the 'seventies and 'eighties, Krupp devoted himself seriously to the discovery of a method of making heavy steel castings of great resisting power, such as crank shafts and gun jackets. The experience of his youth allowed him to give valuable hints for this, though the difficult problem remained for the time unsolved. The first attempts in the manufacture of armour plates were also made in Alfred Krupp's lifetime. It was the last great metallurgical task to which he devoted his attention.

Krupp's proficiency in forging steel went hand in hand with the improved production of it. Under the hammer and at the forge, he learnt to handle cast steel with equal skill and certainty, and while teaching his workmen and foremen this art in his youth, he trained them to the proficiency necessary for the manipulation of his heavy crucible-steel castings. In his youth there were hardly any workmen in German shops who knew how to handle cast steel; even in England it was only worked in light bars. Alfred Krupp often suffered heavy losses through clumsiness, as long as he was obliged to send his castings to be forged at other works. This spurred him on to do everything with his own plant. The forging of gold and coining rolls was a good school in this respect, considering the severe tests they had to undergo in the subsequent hardening. Then came the making of weldless rings for reed and tinsel rolls, afterwards the production and working up of weldable cast steel for mining tools and other purposes, the forging of breastplate, &c. Krupp worked at all these things with his own hands, and later on in the 'forties, he showed, by hollow-forging some gun barrels, that his manual skill was equal in every respect to that of the most experienced smith. By careful attention to the heating and cooling of the steel, he preserved its good qualities even under the most difficult treatment. Krupp was also universally admired for his skill in hardening delicate objects, which he had acquired as a young man in the manufacture of rolls. By improving and enlarging his hammers, and also by what may be termed an instinct for the handling of steel, he finally attained a perfect mastery over the shaping of the largest and most difficult objects. The choice of the most suitable anvil and hammer faces to which he had given much attention in his youth, helped him here. When the first big steam-worked helve hammer was built in 1852, and the giant "Fritz" in 1860, he drew the total sum of his experience together, and showed that he was as great in engineering and designing as he was in casting and forging.

He had very early had the opportunity of training himself as a designer. The mere production of a metal of equal worth was not enough to drive English cast steel from the market. Krupp had to pave the way for its employment in one field after another. He was compelled to fabricate steel articles which would prove the superiority of crucible steel for such purposes, and so to drive the older metals out of the field. For this he needed machine tools, which from motives of economy he had to build himself, and so he first displayed his talent for designing machines and tools. His habit of thinking while he was at work helped him greatly in this. While he was busy at the grindstone, the lathe or the hammer, ideas came to him, how this or that could be done more cheaply and better, and so his genius for machine building quietly matured, till no difficulties were too great for him. He was a skilled workman in almost all kinds of metal work; he could grind, turn, mill; he learnt as a youth to use the planing machine and the difficult work of trepanning; when only 25 he built machines for all these purposes, and for others, for instance, for milling toothed wheels, for burnishing gold rolls, &c. they were all well built, and some of them remained in use till the 'fifties and even longer. Unceasing painstaking and unwearied effort are the great characteristics of this early period of Krupp's development as a designer. The machines were often altered, while they were being made, and sometimes entire portions of them were rejected. A few weeks in the pursuit of an object sufficed to bring Alfred Krupp new ideas and new conceptions of design. Of course, there were some failures and unsatisfactory results, but Krupp was doubtless in many respects in advance of the mechanicians of his time, or at least he was in the first rank. He was acquainted with the milling machine and the press, the models, patterns and gauges, and employed them at a time when they were comparatively unknown; his first contrivances for hardening gold and die rolls stood quite alone in their well-thought-out perfection. It was he who in a great measure initiated the use of crucible steel for parts of machines, and in building his own machine tools he gave this material a prominence which it did not attain till after long disputes in railway rolling stock and machine building. In this domain, too, he went ahead rapidly. His tyre-rolling mill, the hammer "Fritz", the rolling mill for rails, and subsequent additions to the plant, which were mostly turned out from his own shops, proved what an enormous reserve of constructive skill Krupp, still the sole manager of the works, possessed. Even when he left the details to his assistants, the fundamental ideas of the new erections originated mainly from him, as is shown by drawings by his own hand, which still exist. In shaping his rolls, axles, crank shafts, wheels, tyres, &c. he availed himself of his intimate knowledge of the qualities of his crucible steel, qualities which were often counteracted by the wrong shapes which the objects were given by inexperienced hands. Finally, with cast-steel guns he entered on the last and greatest field, on which he could best prove the superlative tenacity and strength of cast steel, and thereby inaugurate a new epoch of ordnance manufacture. Henceforth he devoted his chief attention as a designer to this branch. Here he won his greatest successes, he was admired at home and abroad as the creator of the cast-steel gun, and as the "Gun King" his name will go down to posterity. And he deserves it, for during the latter part of his life, his mind was chiefly occupied with weapons offensive and defensive. The perfecting of ordnance and its adaptation to the requirements of war by land and sea never ceased to engage his thoughts, and even during his last illness he showed an interest in the new domain of armoured shelters and the construction of an armour-plate rolling mill. He hoped to invent an invincible weapon and thereby to take the lead in the production of armoured guns.

But weighty as these technical questions were, and intensely as they interested Krupp, they were only a part of his busy life. The enormous capacity of production which the works attained under his management, resulted entirely from the masterly power he displayed in organising the works and in training his employees. He was peculiarly fitted for this, both by his talents and by his life's schooling, and the larger the factory became, the more attention he devoted to questions of organisation and strengthening, though at the same time he did not neglect technical matters. "I want to leave a great homogeneous whole to my successors; I shall devote my last bit of strength, my last wishes to this:—Money is in my eyes of far less value than this lofty aspiration." He began his career in 1826, as a simple workman with few comrades. But his love of order and organisation soon stirred within him, and when barely 16 years of age, he did all he could to get a clear grasp of the working order of his concern; and by estimates, calculations and memoranda of outlay and production, &c. he raised himself from the level of mere experiment to that of accurate knowledge. There are notices of this date relating to the consumption of coal in the furnaces and forges, to the production of the men at file cutting, forging and polishing. At the same time he tried to organise labour even when his works had not outgrown the stage of a mechanic's shop, and to place it under careful control. He gave exact directions as to what work was to be done on certain days, so as to ensure a quicker execution of orders than formerly, and thus to regain the custom which had been almost entirely lost. If the orders in hand were not sufficient to give the men work, he made them work in advance, as far as his limited means allowed; or experiments were made, or some other work taken in hand, which could be set aside when further orders came in. He tried assiduously to avoid hitches in business, therefore he laid the greatest stress on regular supervision, which with the growth of the works became more and more necessary. "Supervision is more useful than work," he used to say. His mind dwelt much on the future, but he always insisted on the strict measure of daily work; the daily demand had to be punctually supplied. His good common sense taught him that the permanent progress of the works depended on their present prosperity, and he was therefore careful that the ordinary course of business and the prompt execution of orders should never suffer from experimental work. The state of things in his father's time had shown him the necessity of keeping customers in a good temper. He wrote to his friend Sölling who was hurrying him about making the first gun:—"Orders are coming in nicely; that prevents our working at the cannon for the present, and much as I am looking forward to the result of our attempt, still, current orders, which bring in the sinews of war, must have the precedence. Time will show." He afterwards stated his views on this matter in the "General Rules and Regulations":—"The greatest care and attention must be devoted to planning, executing and supervising, so that no stoppages take place, that no surprises of any kind occur, and that every emergency can be dealt with as it arises. And special care must be taken that all jobs, even those about which there is no particular hurry, be finished at once, so as to ensure freedom of action." We find directions, written by him as early as the 'thirties, as to the most suitable way of making tanners' tools and cast-steel rolls. He afterwards compiled similar directions for other branches of work, aiming at simplification of method, at better order and supervision or some other kind of improvement. In these directions he could make use of the detailed knowledge of work that he had been acquiring from his very childhood, he could make use of his personal experience, and of all the mistakes that could be made in the works. Later on his great object was to train the subordinate members of the staff to a self-dependent discharge of their business, and to lighten the work of the higher officials, so that the latter could control and supervise their departments without entering into every detail.

For many years Alfred Krupp was the sole master in the works, managing and supervising the men; and when the appointment of foremen and managers of shops was necessary, he was very careful in choosing them, and for a long time kept the choice in his own hands. They were not to be taken from those who inclined to "good living, dressing gown, and slippers". He demanded of the foremen that "they should give their hearts and minds to the work of all their men and its success". That was a requirement which sometimes the most capable workmen could not fulfil, and when such a one was proposed for a foreman's place, Alfred Krupp, who knew his men thoroughly, used to refuse his assent. He had little respect for "clerk's work and manual labour" among the higher members of the staff. "Work less, and supervise more" he would say, or:—"Eyes and legs are necessary. The manager of a workshop ought hardly ever to be found in his office." The rule he laid down for the heads of shops and foremen was as follows:—"The engineers and foremen must always begin and end work with their men, otherwise there will be no order or conscientiousness. The Cast Steel Works have attained their present eminence by studiously following these rules, that is, by true diligence and constant supervision. Formerly, the full powers of every man employed were constantly called into play, and no one could take the place of another. Now efficient substitutes can be provided for any one who needs rest and change after a long period of strenuous work. The end can therefore be attained." The foremen and engineers had to understand the men and to get on well with them. Those were preferred who had worked their way up. "He who has earned his bread by the labour of his hands is worthy to be a master." He considered this a primary condition for a good understanding between foremen and workmen. In the selection of the staff, the merit of a man and his suitability for some particular post settled the matter. Krupp was an avowed enemy of all favouritism, and never allowed personal recommendation to bias his decision. "Everything must be settled according to the prescribed regulations. Friends and relations have no better claim on the firm than strangers. The quality of a man's work alone decides his position there. Who would care to get an appointment in a business, where any one can claim privileges? Help of that sort would only lead to ruin." When the "Procura"—the present Board of Directors—was instituted, he was most careful to define their exact position, to invest them with the proper authority, and to direct their work into the right channel. In choosing his directors he sought in the first place foresight, decision of character and a talent for organizing. The Procura were not to burden themselves with attention to details, so that they could have time for more important matters. "The Procura must have time and leisure and the good-will to manage the whole according to my ideas; that means far more than attending to the current business. It means, a man must have leisure, time for thought, for working matters out and going into them thoroughly; it demands clear insight; and the desire to gain a clear conviction, when this has been reached, it must be accompanied by force of will to carry it out." He required initiative in the part of his collaborators, and the adjustment of all differences of opinion which arose at the board meetings without his interference. "In the directing body, any disagreement occurring must be settled without me, and occurrences of like nature must be avoided in future. I will have nothing personally to do with disputes, and I beg every one to consider me in such matters as already dead. For some day or other you must manage without me." On one of these occasions he wrote:—"All must be done in harmony; only those who are well-intentioned and intelligent—not those who are ambitious and selfish—may give their advice; every extraordinary matter must be discussed by all." Thus he placed the general responsibility of the Procura beside the individual responsibility of every member of it in his own department, and made this the leading principle of the co-ordinate constitution of the directing body of the works.

Alfred Krupp was aware that the true basis of all good organisation is to give the right work to the right man. Thence he derived his maxim:—"Never do yourself what others can do," and he applied this rule to his own work, and to the division of business and responsibility between the upper and lower members of the staff. He knew that much of the success of a great undertaking is guaranteed by the authority vested in everyone in command. If, however, it was his rule to uphold the authority of his staff, he very well knew that their authority could not rest on the mere right to give orders, because they had been placed in a certain position. He saw that it was far better assured when the subordinates are convinced that their superior not only has a knowledge of their work, but undertakes the most difficult part himself. Therefore he paid strict attention that the power of command was properly distributedamong the various departments of the works, that the limits of action were clearly defined. He fixed exact limits within which each official not only might but must decide. He insisted on strict adhesion to all the regulations. He looked on order not only as the keystone of success, but also as the best school for inculcating self-reliance and a sense of responsibility. He desired that the future of the works should be assured, as a great state is protected from arbitrary government, by its constitution and legislation. This desire led finally to the issue of the General Rules and Regulations in 1872, by which he tried to settle "for all times" the rights and duties of all those employed in the factory, and the contents of this document are very significant of the whole bent of his mind. "I must be sure," he says, "that 25 years hence, or 50 years hence, no disorder can possibly be brought about by evil intentions. The Regulations must prescribe the course of action, every emergency must be foressen, every man's rights and duties must have their allotted status."

Lastly Alfred Krupp regulated his own many-sided and comprehensive work by these principles. For a long time he turned his hand with diligence to everything, great and small, that was done in the works, even in little jobs he had been among the foremost workers. In his youth this eager activity accorded with his temperament and inclinations. But as the works developed, he sought to bridle his eagerness for work, and by abstaining from less important matters to reserve his time and powers for real management and great questions. He tried to school himself for the higher tasks that presented themselves to him. His diligence, his capacity for work were intensified when he concentrated them on the development and improvement of the works and on assuring their future. His wish was to cease from taking an active part in ordinary business, and only to interfere personally when complicated or weighty matters had to be decided. He did not shrink, however, from taking the whole responsibility of such cases on himself, and when he did interfere personally it was with decision, even sometimes with sharpness. He once replied to a remonstrance of the directors by saying:—"When a resolute man is convinced of the justice of his case, he marches straight against his opponents—the right demands the courage." Still he had an instinctive feeling that his personal authority gained in weight by not being exercised in the daily routine of work. He reserved his judgement as long as possible, like that of the highest court of appeal, and he avoided bringing the odium of a decision on himself, which could be given according to the prescribed rules in a lower court. His talent for organisation made it clear to him that a large and complicated business could only be kept going harmoniously by this means, and he thoroughly understood the conditions under which a large number of men of various grades can be kept working together for the common good and prosperity. It was, truly, not always easy for him to act according to his principles in this matter. Sometimes in his old age, when he was worried about the future of the works, he could not refrain from interfering with matters, which from his exalted standpoint he was no longer able to follow. He had really meant to close his personal work in the factory after the issue of the "General Rules and Regulations", which he had worked at with the utmost eagerness. "As the hart for cooling streams" he said, "so I pant for order." He wished to be considered a dead man. In the middle of the 'seventies he writes:—"Even on principle I should interfere no longer, so as to convince myself during my life that the works can go on without me," and again, "My only personal participation in the management is now restricted to completing the work of the Procura by my brains, my energy and my position. That I strive to do." and further "The sooner my work can be considered superfluous the better pleased I shall be. I am longing unspeakably for the word to be spoken: He may go!" Sometimes he even said:—"I will do nothing at all. I will be a mere cipher." Here, too, his guiding thought was for the future. The idea, that he himself could, to some extent, be replaced in the works even during his lifetime, he applied to everyone employed. Knowledge and experience he said, ought not to be kept shut away in any one's head, or perhaps in a pocket or a writing table, so that they should vanish with the death of their possessor. Everything must be so disposed that no gaps should originate. "My one wish is to find so good a substitute for myself, that I can retire any day, and every man should wish the same thing. If the whole unity and management depends on one man's health, the whole thing is in perpetual danger." And as he surrounded himself with men whose worth had been tested, he required every one who held an important post to find "such a locum tenens, that no illness, no holiday, not even death, should put out the clockwork of the factory." But in spite of all this, his temperament and his delight in work drove him ever again and again to occupy himself with details.

Alfred Krupp's work as an organiser was furthered by his habit of regulating all his actions by strict principles. Impelled by his love of order and his abhorrence of all that was arbitrary, he early devised a system, which became his rule of life, and he soon carried this system into what he did for the factory. It was his nature to generalise, to deduct the important and permanent from separate experiences and events. He considered the successful management of big works only possible when each detail can be traced back to some central idea, and considered in relation to that idea, and to its effect on the whole. "The future of the establishment does not depend on the number of orders in hand, but on the general wellbeing of the whole." He classed no occurrence as unique and peculiar, it was to him symptomatic, and of weight in estimating both men and matters. He was prone to over-estimate both good and evil:—he was aware of this, but he felt it necessary to the fulfilment of his task. "Good and evil ought to be viewed through a magnifying glass; therein lies the truth; for as we obtain wholesome or poisonous fruit according to the seed sown, so the deed springs from the character." Alfred Krupp formed a number of such maxims for himself, which he developed into rules for success, and carried out in the works with the tenacity peculiar to him. "The first principle we must follow is that the manufacture must be of the highest excellence,—as far possible perfect." This is the first sentence in the General Rules and Regulations. Krupp had learnt in his youth how seriously the finances and the reputation of the works could suffer from the delivery of inferior goods. From that time he was determined to make the standard of excellence the first law. He did not snatch at temporary success, or the highest profits, he worked with his eye as much on the future as on the present. "To produce low-class work does not appeal to me," he used to say in his youth. On this point he made no concessions, and when cheap competition sometimes caused him heavy losses, he never grew impatient, but always trusted in the final victory of good work and material. He had no great opinion, either, of the arts of persuasion and advertisement. He wanted customers to come to him because they were convinced it was for their own advantage. "The value of our work, impartially weighed, must bring us work," and "the biggest bargains are always made with the fewest words." He valued excellence in work so highly that he would not hear of economy in the purchase of good raw material. When the works were beginning, this principle had not been observed, because they were short of money, and great damage had ensued, so that in later years Krupp was very strict in the matter. He endeavoured to raise the methods of production to perfection in every respect as far as it was possible. "Constant and careful attention must be given to building the most suitable machines, and to employing the most perfect methods of manufacture. He watched over the execution of these rules in the works with the greatest strictness. Every defect was the occasion of an investigation of its cause, and of the way to avoid it in future. He laid great weight on thorough supervision. He would not rely solely on the skill of the workmen. To trust to that alone he called neglect. "Every accident is the result of lack of prudence, that is to say of carelessness; what one calls putting trust in others is in reality laziness." Not only the work, but also the articles produced had to be carefully inspected, and that not merely when finished, but also at different stages of manufacture. Every workshop which took over raw material or half-finished articles from another shop, had to test them carefully before accepting them, and to report any defects at once. He tried to establish the reputation of his works with the world at large, by giving a thorough guarantee for all finished articles. The first of these guarantees were given at the end of the 'twenties for tanners' tools, and in time they became one of the keystones of the business. But in exchange for this care he liked to have the excellence of his goods properly recognized. He always attended to justifiable complaints, but customers who were always grumbling without good reasons were put into his "black books," and sometimes he would execute no more orders for them. "Grumblers are the ruin of a business" he would say. In all such cases, he demanded a thorough examination of the goods, took the opinion of trustworthy experts, or he insisted on a formal apology from the complaining party, so as to shield himself from public attacks. Krupp was seldom inclined to make reduction in price. He did not like bargaining and he rightly feared that the practice, if persisted in, would lead to deterioration of the quality of the goods. These ideas and principles often resulted in a harshness of manner, which customers did not care to put up with, and which often cut a transaction short. A characteristic remark was made to Krupp's agent by the well known Bavarian industrialist von Maffei who valued Krupp's cast steel very highly:—"Fortunately," he said, "I have no orders to give you. When I have the misfortune to be obliged to order something from you, you may be sure I shall do so." The introduction of new articles of manufacture was often delayed or rendered difficult from this cause. But on the whole the maintenance of these principles firmly established the reputation of the works, and led to their brilliant success.

In his economical ideas Alfred Krupp showed a talent for careful management which could draw profit from every thing however small. He set his face firmly against all unnecessary outlay in production, and while he allowed no economy in the quality of his raw materials, every waste of the material itself was strictly avoided. The scrap had to be carefully collected and turned to the best possible use. "I never come to the works," he used to say, "without saving a bit of iron, a screw, or a nut, from being wasted. The very nails ought to be looked on with respect." "All waste must be avoided in the use of raw material or of scrap. No machine — no power must ever stand idle, and thrift must be active on all sides." He insisted on the same principles of economy when setting up new building and plant; he would not let the cost of production be burdened by unnecessary expense in the erection of workshops. He always started with the least possible outlay, and though he kept his eye on a great ultimate enlargement and extension, he would not launch into great expenses from the first. The workshops were at first built small and cheaply — all extensions he made temporarily. "Begin and enlarge in the American fashion" was his advice, and when during his absence, in the 'sixties, too much had been laid out in fitting up newly-built workshops, he was very angry. In 1871 he ordered that all outlay for plant which has no further object than appearance, style and decoration be once for all excluded. Another time, in speaking of his own modest beginnings, he said:— "The greatest merits of a designer are simplicity, cheapness and solidity combined. To build luxurious workshops and sheds is a piece of showing off before the public which must be paid for with the life blood of the purse, and which has blasted the beginnings of many enterprises." Still these ideas did not lead him into parsimony. When he knew it was necessary, he would invest in the costliest machinery. He provided not only for present needs, but did not shrink from erecting the most expensive plant when he felt that it was necessary to future success. The maxim "small beginnings, great ends" guided all Alfred Krupp's conduct in business. It was here that his peculiar combination of prudence and caution with daring and farsightedness was most clearly seen. He was particularly cautious about the adoption of technical changes, before they had been thoroughly justified by experiment. Shortly before his death he expressed these ideas in an admirable letter to his Procura:—"I would recommend as a rule for all time, that in making experiments, every problem should be studied on a small scale, before proceeding to carry it out on a great scale. A man may ruin himself by extensive experiments before he has solved the problem before him, but if he begins on a small scale, he can see what is lacking, and what is indispensable, and he can only advance step by step when he is sure of ultimate success. Such problems require unceasing application, and even more of caution and reflexion, if a man would gain experience and avoid fiascos. Time is also gained, for it is easier to discover the right way quickly when the experiment is made on a small scale before completing it on a large scale. As long as a doubt remains nothing must be attempted on a large scale, nor till small experiments have shown the certainty of final success. I should like to have this rule printed in letters of gold which all could read, and hung up in every office and shop, so that every one in authority could lay it to heart. By observing this one rule I have made my way upwards, and though I began without any resources whatever, I have attained the most important objects:—whereas I can recall a number of instances in the past, of engineers and enterprisers having ruined themselves at the very start, by beginning on too large a footing. I can only repeat, that without this caution,—in addition to the most dogged application to work,—I should not only never have emerged from poverty, but I should have been totally ruined fifty years ago and a hundred times since. If this rule be kept, now and in future, if it is never neglected by over self-confidence, vanity or indolence, the ship will always lie firmly anchored." But when the way was clear and progress certain, he,—otherwise so cautious,—threw aside all hesitation, launched into any outlay and marched resolutely forward to his goal. He was ever ready to sacrifice the fruits of his labour to the next step forward, and to stake all on the prospect of a future great success which no one believed in but himself. During the 'thirties, for instances, after introducing his cast-steel rolls among the German goldsmiths, he immediately began to enlarge the works, and to set up a steam engine,—which was a great strain on his finances—so that he might proceed to gain a foreign market for his goods. To his friend Sölling, who often reproached him with daring to set up new plant, he once gave the answer:—"We might really take money out of the business for our own use. But we will instead put all that we can scrape together into it,—we cannot make a better investment. How can we know to what extent any single branch of our business may increase?" As long as he believed himself to be on the right track he took no notice of financial difficulties, though he was often reminded of them. It was in a certain degree his way, not to over-estimate such difficulties, his hopeful optimism and his trust in the future kept him from doing so. Such ideas are necessary for a man who ventures on new paths, and they were confirmed in Alfred Krupp by long experience; for in spite of all the warnings and forebodings of his friends, he always succeeded in ultimately vanquishing all pecuniary difficulties. At the beginning of the 'seventies, certainly, this great hopefulness was nearly fatal to him. At that time he took tremendous obligations upon himself without any absolute necessity, and this, in consequence of the crisis of 1874, placed him in a very critical position.

* * *

As head of the works Alfred Krupp exercised a great influence on all around him by his mere example. The very workmen caught the spirit of self-devotion and industry which glowed in him, begetting a readiness and willingness to work with him. The amazing success of a man who had once stood in the ranks of his own workmen, and had raised himself by his own abilities to the foremost place in a gigantic undertaking, combined with his striking personality, produced a powerful effect on the imagination of all. But Krupp's influence was even more felt in the care he bestowed on training his employees. He was their teacher in small things and in great. He believed everything might be attained by careful instruction and training, and he strove to inculcate in his fellow workers all his personal qualities, all that he had learnt by experience or deducted from business maxims. In his youth he himself taught the men—who were mostly taken from the plough—their work, and he often resorted to rather drastic measures; for instance, a turner, who had spoilt an axle, had to hang up the damaged work over the lathe for a considerable time, so that he might have the result of his carelessness before his eyes. He expected a great deal from his men, and considering his character, we can understand that only the most capable could come up to his expectations. His works were to be served by the most competent in every department; and those who could not or would not walk in his ways were out of place there. And when he himself could no longer make this selection, it was his constant endeavour to impress all his managers with the importance of it. The men were to be judged solely by their work, and kindness or severity was to be dealt out according to the deserts of each. He did not shrink from taking severe measures when necessary, and he demanded the avoidance of any show of weakness that could be resented as injustice. "We must draw a sharp line between good and bad, both among the managers and the men, we must always recognise the one, and reprimand the other, by rewards and punishments. Justice and the interests of the works demand that every man shall get his due" and again "Severity is as necessary on the whole, as kindness and justice. Though it is not possible for us to requite loyal service too highly, still we must not heed public censure when we have to punish meanness and baseness with the utmost sternness. I should not hesitate to make the greatest sacrifice rather than hear our weakness derided." The greatest candour and frankness had to be maintained between himself and his fellow-workers. "Candour on one side demands candour on the other," he used to say, "in no other way can we expect a blessing on our mutual relations." He spoke his own opinion frankly, and liked every one to be equally frank with him, both in differences of opinion and in any disagreement which had occurred in the works. "One thing is needful," he once wrote, "that is truthfulness and frankness from me to you, without any flattering compliments, to these latter I have never accustomed you, except when I meant them in perfect honesty, loyalty and friendship"; and again "I must really be pardoned, if I express myself quite openly in serious matters. Every one must be good enough to do the same, and no one should be offended since no personal interests, but only our great mutual ones, are at stake."

Though Krupp insisted that all mistakes should be strictly investigated, he was, on the whole, gentle with those who made them, when he had no reason to suspect their intentions. He used to say:—"He who works, makes mistakes; I make some myself. He who works a great deal makes more; it is only the man who sits with his hands in his lap and does nothing at all, who cannot make any." But whenever and wherever he met with laziness, indifference or want of attention, "letting things drift" as he called it, he was inexorable, nor would he suffer such men in the works. He expected constant punctuality and application to work from every he employed. When business was slack, he required redoubled zeal, and he tried to keep the men on, even at a loss to himself. Thus he banished idleness and depression from the factory, and kept the working powers and the responsibility of every one up to the mark. He tried to bring out the inventive powers of the managers and the foremen. "We must be the first in the field with every improvement, we must not go stumbling along in others people's steps. We have the brains and muscles, and I have never doubted that we have the good-will too." He expected complete self-surrender from both managers and men. His fellow-workers had to give all their energy to the works as he did himself. He had a horror of anything which infringed on this, of every occupation that was prompted by inclination or ambition. "There is positively no room for any other occupation whatever. If we make exceptions we shall live to see the day when men come to the works to rest, and go home to work, so as to earn something extra. The one will write books, novels or poetry, another will make plans and estimates for building houses and machines for other people, in short, one abuse will follow the other." The General Rules and Regulations resumed these words as follows:—"We require that every man who belongs to our corporation shall at all times loyally and strenuously promote the welfare of the firm and protect it from harm; and we demand from all:—regularity, punctuality and continuous application to work. Therefore every man must devote himself entirely and exclusively to his profession, and when the business in hand does not claim all his time and attention, he must employ them for the firm in some other way. The higher officials must utilise the time they have over from their immediate duties, for the benefit of the whole, by regulating, revising and considering business matters, drawing up proposals, &c. Thus every secondary occupation, whether it be for private gain or for public service, is prohibited." The employees and workmen were to stand by the works as a soldier by the flag, and each, as a member of a great body was to do his utmost to promote the welfare of the whole. As the head of the corporation he claimed the prerogative of inquiring into the attitude of those he employed towards the works, and to remove those who were evilly disposed "for actions must be judged according to the spirit which inspires them".

If Alfred Krupp, however, exercised his authority with justice and severity, he was also prepared to make a noble return for the work and loyalty of those he employed. He was actuated in this by his sense of justice, his respect for work, his gratitude for loyal service, and above all by his conception of the highest aims of the works. He considered them as a means for promoting the welfare of all those who belonged to them, from the highest to the lowest. Thus the workmen were first paid out of the profits, punctually and liberally. This was for him a matter of course, and necessary in the interest of business as he conceived it. But he went far beyond his obligations in this matter, and did not hesitate to make his own view of the moral obligations of the firm binding on his successors, by the General Rules and Regulations:—"The firm shall not consider its duty exhaustively fulfilled, when it has satisfied all the legal demands specified in the contract; it shall rather be its endeavour to reward loyal service and excellent work in a special manner, and shall always loyally respect and honour those who have devoted their powers to it in honest unselfishness." Krupp's heart and hand were from the first open to people of small means, and he took much thought how to lighten the load of the poorest. Later on this desire to help found its expression in the provisions he made for his workpeople, which he began on broad lines very early and afterwards during the 'sixties and 'seventies, developed into his grand system of institutions for the welfare of his workmen. These noble institutions added another keystone to his life's work, and not only indicated a path for his successors, but gave an example to the whole industrial world and to subsequent social legislation. This is an imperishable honour.

Thus a personal bond was formed between Alfred Krupp and his employees and workpeople, a bond as useful to harmonious co-operation in the works, as it was indispensable to his warm heart. During the first twenty years or so, when the number of workmen was still small, their relation to one another was that of intimate hearty comrades. It was a reflection of Krupp's kindness and humaneness, and the old workmen repaid him with touching love and admiration. They would go "through fire and water for him", and at a push he could make any demands on their work and devotion. "They were happy when they saw Herr Krupp," the oldest foremen would say, when they talked of bygone times. Shortly before his death he mentioned the names of seven faithful companions who had helped him to re-establish the factory, in 1826, and he added in his own manner:—"with Alfred Krupp there were eight." This close personal relation to the old workmen had grown out of daily intercourse in the shops, where Krupp worked among them, giving and taking advice and counsel and sharing in their joys and sorrows. During this time he learnt what the presence of the master in the workshops means. "The master's eye," he used to say, "does for the men what grooming does for a horse." As the number of hands increased he tried successfully to keep up this intimacy. He laid frequent stress on the necessity of close intercourse between the head of a work and the men:—"The main thing is to be always about among the men, to notice them and chat with them, it raises their self-esteem and gains their hearts and their loyalty." He set an example in this himself. He would often in later years go and smoke a pipe, or have a chat with his former friend Johann Schürmann, whom he had taught to use the lathe, and whom he had allowed to put his name to the contract of purchase of the works in 1848. His confidence in some of the old foremen was unbounded, and when he no longer came regularly to the works, he used to discuss matters with them by letters. In cases of illness he showed them hearty sympathy, and often wrote them letters. To the foreman Pelz, an experienced hammersmith, he wrote with his own hand:—"Dear Pelz. Be as careful of your health as you are of heating and forging." In 1879 he wrote to the hammersmith Heinrich Strünck, a character among the "old guard" who could neither read nor write, but "who wrote a good hand with the hammer":—"I send Meister Strünck, my good old friend, a pipe as a remembrance, hoping that he will soon be restored to health," and in the following year "My dear Meister Strünck, I regret to hear how very ill you are; I am extremely sorry, because I have always respected and liked you. From your youth up you have always had the welfare of the works at heart; you have always set a good example, and you belong to the number of those faithful ones who by their thoughts and deeds helped me to establish the works. I send you my heartiest good wishes for your recovery. With kindest regards, Alfred Krupp." As the works grew larger, he could not possibly keep an eye upon each workman, and he desired the foremen to be, as he had been, the friend and confidante of each, therefore he made stringent demands in the selection of foremen. In the course of time, he lost all personal contact with the mass of the workmen, and it was uncongenial to him to seek popularity by making addresses or speeches on special occasions. When he visited the shops, he stopped to talk to none but the old workmen about their work. But his active sympathy and love were given impartially to all who were employed. On suitable occasions, such as family events, royal birthdays and the like, the relationship between the family and the works found expression in festive gatherings. Later on, he showed his appreciation of work as the foundation of the factory by making special gifts and endowments on these occasions. But even in this, the result did not always come up to his expectations and Alfred Krupp, more than once experienced disappointment and ingratitude. Many things that he planned turned out otherwise than he hoped. In speaking of the endowments made in the 'sixties, he said they were made in the hope of binding those benefited more closely to the works, but the result had been quite different, and in many cases prodigality and thriftlessness had been occasioned. So, in the course of time, his opinion of the way in which the workmen might be helped and made happier, was considerably modified, but his sentiments on the subject remained unchanged. And as he grew old, a touch of resignation and subdued bitterness clouded the expression of his benevolence towards the world in general, and his workpeople in particular. Moreover, in his old age, he was less in touch with the world than he had been in his youth; it was hard for him to make concessions to the new times, which seemed to him to have become—with their inordinate love of speculation,—nervous, hurried, superficial, and pleasure-seeking, and on the whole far from satisfactory. He had little pleasure in these times, and indeed the simple tastes which he had inherited from his parents were out of place in such an atmosphere. The growing tendency for show and luxury was not to his taste, and where he could not check it, he carefully kept out of its way. But this did not deter him from creating those comprehensive institutions for the welfare of his workpeople, in which his philanthropic spirit found so noble and far-sighted an expression.

The older Alfred Krupp grew, the more use he made of writing as a means of working and instructing. After he retired from the personal management of business, it became more and more his habit to convey his idea and directions to the Procura in writing. He never wearied of putting down his ideas about ways and means of improving the works; words of encouragement for his workers, or judgement of different events. He wrote enormously in letters, on journeys, even while playing billiards or at meals, most of all in the sleepless hours of the night, for which paper and pencil had always to be placed within reach of his hand. His way of expressing himself in these documents is characteristic of the way his mind worked. His style, with its long sentences, was heavy and inflated in his youth, and exactly corresponds to his struggle with his ideas. It demands attention and thought, but as a rule hits off what he wants to say. He is always trying to convince his reader, and to bring him over to the views he is expressing. In course of time, he became more concise, sometimes as brief as a telegram, or his words would be condensed into axioms, which immediately imprint what he says on the memory, by the avoidance of every unnecessary word. He set great value on clear expression and the avoidance of ambiguity, elegance of style was a matter of indifference to him, though we often find similes and figures of speech which show how his imagination worked while he was writing. His similes are numerous and telling:—"Regularity is like a comb. If you are used to it from your infancy, it is pleasant and finds no resistance. But if the hair has been allowed to grow into an uncombed tangle, its adoption is a painful operation." He was fond of adding a moral reflexion to facts which he related, such as:—"Without such caution I should have been ruined a hundred times" or in speaking of his old home, "This house and its history can give courage to the timorous, and teach perseverance to all. May it be a warning against despising small beginnings or giving way to pride." He liked to express his maxims in proverbial sentences; such are often found in its writings. Some have been mentioned already:—"The aim and end of labour must be the good of all." "Shabby work is not to my taste." "Begin in a small way, stand firm under difficulties, follow lofty ideas." "Lotteries are contrary to my principles." Others run thus:—"Strength delights in work." "He who gains success, makes enemies." "Sleepy folk must be shaken till they wake." The whole of Alfred Krupp's correspondence with his Procura has been preserved. It fills thousands of sheets with his firm, clear handwriting, and contains all his ideas and opinions, and his rich experience of life and business. It is, in a certain sense, the fruit of a life which was abundantly blessed that he has recorded in general observations and practical hints as to the manner in which business questions must be dealt with; an inexhaustible mine of instructions for his successors and for all who are called to take a leading part in the works.

* * *

During the 'seventies Alfred Krupp began to visit the works less regularly and to leave more and more of the management to the Procura. He had hurried the time of the General Rules and Regulations, hoping that this would bring him the emancipation from daily business for which he longed, as the infirmities of age grew upon him. He was truly in great need of rest, for half a century he had worked without sparing himself, and his best powers were exhausted. "I am very tired, nervous, ill and broken down; I cannot go on like this any longer," he wrote in 1877. Besides the factory had grown so enormously that he could not possibly take the same interest in its every detail as he had formerly done. This he saw plainly.—He was convinced of the necessity of retiring from work and yet he could not act on his conviction. This discord between what he knew was right and what he did, was the more painful to him the more clearly he felt it. Werner Siemens ceded his life's work to his sons, and retired into the domains of scientific research, when the extension of his factory went beyond his liking. Hermann Gruson took leave of his creation and gave himself up to his personal inclinations when his works demanded more than his strength could give. In both cases the separation was painful. But Alfred Krupp could not make up his mind to this complete renunciation. He clung to the work of his life with every fibre of his being, so closely that he could not wrench himself from it. He knew what his personality had been for the works, and he feared for their future, if he gave up his place. He put this in his usual way:—"There are factories which can get on almost by themselves, while in ours, improvement must be striven after daily, and for this I must use the last remains of my energy, even if I cannot come to the works every day." His past was too closely associated with every detail for him to be able to raise himself completely above them. He forgot that he had gradually grown out of these details, and that now others must carry out his wishes. It was often very hard for him, to see what really his own work, done by other men, and the truth of Goethe's words was forced upon him:—

"Was Gutes zu denken wäre gut,
"Fänd sich nur immer das gleiche Blut;
"Dein Gutgedachtes, in fremden Adern,
"Wird sogleich mit Dir selber hadern."

But he could not act accordingly. Now as ever, all his thoughts, all his endeavours were directed solely to the works, and the less he went there, the more their welfare occupied his mind. However much he wished, he could not rest, or remain idle; he was impelled to work, ponder and worry just as of old. But his courage and his delight in work were no longer the same. What his trust in the future had hitherto always overcome, got the better of him in his old age, and he began to be anxious about the continuance of the works. And the documents by which he wished to secure the cohesion of the whole "for all time," become more and more passionately insistent. There is really a touch of tragedy in Alfred Krupp's extreme old age. Who can venture to guess what took place in that fiery soul, before that firm faith in the future could suffer even an occasional shock? The events of the year 1874 certainly had their share in the change. He saw everything around him tottering and unsafe; his confidence was shaken to its very foundations; and what must have been his feelings when in his bitter need, he had to lay on his works the burden of a loan borrowed on hard conditions. Did he, in his heart of hearts, take some of the blame to himself, or had he partly lost faith in himself? We cannot determine this from what he wrote at the time, but if we could, much light would be thrown on his character during the latter years of his life.

Old age brought out many traits in Alfred Krupp's character which had lain hidden during the prime of his life. Two of these especially; impatience and mistrust often got the upper hand now. This rendered the task of the responsible managers very difficult. From the time that Alfred Krupp shook off all the details of business and could follow out his thoughts more at leisure, technical ideas and plans suggested themselves to him in abundance. He overwhelmed every branch of the management with notes, memoranda and directions, which were far more than could be carried out or even thoroughly examined, along with the usual routine of work; so much had to be postponed, and much lay untouched, while he was waiting impatiently at the Hügel, for a report of results. When he waited in vain, his temper sometimes broke out in violent and unjustified reproaches. "I cannot and will not repeat myself. What I have written shall not be thrown into the waste-paper basket. Lots of things are neglected, because those in authority have not taken the trouble to acquaint themselves with my wishes and reminders." A growing inclination to hold by an opinion he had once expressed, and his increasing dislike of verbal discussion, made it very hard to come to an understanding with him, and yet he expected any one who did not share his opinion to state their reasons for dissent. "When your opinion differs from mine, I wish you to justify it." He would not be put off "as somebody who had nothing more to do with the matter", and he had been too often alone in the right during his life, not to feel justified in his self-confidence or even obstinacy. "You will see afterwards that I am right," he would reply to objections. But if any one went quietly his own way, he was in danger of being set down as an "ill-willed opponent", in whom Alfred Krupp could put no trust. "When I, an experienced old worker, give myself the trouble to think things out day and night, and to write them down, there ought to be men who read them with pleasure, and see that they are attempted. It does not matter to me, if theorists do not believe in them, or have never heard of them, and doubt them because they are not printed in a book." Moreover, Krupp had the usual inclination of old men to see the past through the glamour of memory, and to compare it unfavourably with the present. "There was a time," he used to say, "when men understood a half-spoken word and could guess my wishes. That has changed very greatly." These fits of depression must be chiefly laid to the charge of his vivid imagination, and his tendency to magnify everything, they often overcame him when he was alone, or in the sleepless hours of the night filling him with unfounded fears and misgivings. Then he could not rest till he had worked off his feverishness in long agitated letters. All his endeavours to shake off his melancholy were in vain; neither art nor nature could divert his mind from its one great preoccupation:—the works. He himself suffered more from his fits of suspicion than others did, for he was aware of the injustice of many of his reproaches and acknowledged it freely:—"I hope you will have patience with my irritability; it is really the result of my hard life and my health." In his dark hours Alfred Krupp was inclined to that contempt for his fellow-creatures, which highly-gifted men who have been often disappointed, seldom escape. Not that he failed to appreciate loyal service, but as he grew old his respect for mankind declined, and his trust in the individual followed suit. He had seen too much narrow-mindedness, selfishness and weakness to have kept his faith in his fellow-men undimmed. But his kindness and philantropy remained undiminished. Though he blamed mistakes sharply and unsparingly, he had always a word to say in extenuation of the error, if it had not occurred through ill-will or laziness, and he often repeated the request that those who had made mistakes might be spared all disagreeable consequences, as he wrote "for the general good", and only required "regulations which should prevent the recurrence of such things". In this he persevered till the end of his life. He wished to live in peace and good will with all men, he was only inexorable when he recognised baseness or treachery as the mainspring of action. The old geniality in personal intercourse which no one could withstand, was proof against all differences of opinion. "Herr Krupp is not easy to get on with, though he is personally very aimable" and "one cannot be vexed with him, for his amiability is quite child-like", are the judgement of his old friends during the second half of the 'seventies. His love of doing good and giving pleasure increased rather then decreased in his old age, and this touch of pure philantropy shed a softening light over the close of Alfred Krupp's life.

In his last will, which relates almost exclusively to the future of the works, Alfred Krupp regains the firm faith in the future which brightened his best years. By initiating his successors into the magic circle of his own thoughts, he raised a secure support for the future continuance of his work in his own spirit. By means of this important document his hand still guides and sustains the works. His one great object was to enforce the principle that the real object of the factory should not to be enrich its actual possessors, but that it should serve far higher aims, by ensuring the permanent welfare of all those employed in it. Therefore he provided that the factory should remain in the possession and under the management of one owner, so that the first condition of lasting success:—pecuniary independence—might be secured. His testament says:—"In making these provisions I have the object in view:—to preserve the factory I have called into existence as long as is legally possible, and to extend it as much as possible." The clauses are in part made legally binding, in part they only lay moral obligations on the heirs. As to the former, Alfred Krupp left his entire property, *i. e.* Cast Steel Works, with all the outlying works, and all the plant, all investments and stock and all assets and liabilities in entail to three successive heirs, as was legally permissible. "Considering the incalculable fluctuations of such industrial works," a sale on the part of the living owner was not prohibited. But the property was not to be split up by inheritance, and Alfred Krupp addresses the following urgent request to the last in the succession of entail "that he will make such dispositions of the property as shall ensure its preservation and improvement". Full of hope he gives the works to his son, with the words:—"I am persuaded that my son and his children will continue to work in the spirit that has inspired me, and that they will consider it of the highest importance not only to maintain the works at their present level, but to devote the largest possible share of the profits to improving them, and wherever permanent advantage may be gained, to extending them." The profits made by the works are to be entirely at the disposal of the owner for the time, and the testator scorned to fix the annual proportion of them which was to be used for improvements.—In order, however, to avoid future disputes and misunderstandings, he says:—"Improvements and extensions which have been undertaken by one owner of the works, shall form an increment of the entail". Thus Alfred Krupp provided with his last breath for the welfare of the factory. His testament is the last stone that he fitted into the great building and at the same time a worthy and lasting memorial of his care for the future of his creation. It shows once again in his passing away, the relation he stood in to his great work.

On the 14th of July 1887, after a short illness Alfred Krupp passed away from a life that had been a joy to him in spite of all its "labour and sorrow". On the evening before his interment, his mortal remains were taken, as he had desired, from the Hügel to the little house in the factory, where the hard years of his youth had been spent. On the 18th of July the works were closed. The clang of the hammers, the roar of wheels was hushed to show a last honour to the dead lord and master.

In 1892, those employed at the works erected a bronze statue at the gates of the Cast Steel Works, as a sign of their love and respect for him who had left them. The tall slender figure of the "old master" stands like a faithful Eckhart before the gates of his works. His eye ranges over the turmoil of workshops and the smoking chimneys. Two figures sit at his feet:—one represents the activity and one the benevolence which occupied his whole life. Thousands and thousands pass this monument daily on their way to the workshops. The number of those who find permanent work and a good livelihood in the Cast Steel Works has increased year by year. The hope which Alfred Krupp expressed in his last will, and the trust with which he left his work in his son's hand have not been disappointed. May his spirit ever rest on the works and bring them to perfection, so that his beautiful saying will remain true:—

"The end and aim of labour is the good of all,
"Such work brings a blessing, such work is worship."

* * *

Monuments have been raised to the memory of Alfred Krupp by his workmen, his fellow-citizens, by engineers and scientists, and in the presence of these proofs of gratitude and regard, one last question calls for an answer. What is the lasting significance of the creator of the Cast Steel Works, if we set aside his creation? What is his place for posterity, and in the history of culture? James Watt is called the inventor of the steam engine, George Stephenson the father of the railway system, Werner Siemens the creator of applied electricity, the names of Bessemer, Nasmyth, Gruson and many others are connected with important inventions and improvements which have opened up new roads for industry, commerce and engineering, and thus may rank among the pioneers of civilisation. The lifework of Alfred Krupp comprised no such revolutionizing invention, no such central point round which all his activity was concentrated. Many inventions were made by him, some of far-reaching importance, many others were made in the works under his guidance and stimulating influence, but the value of his name in history, his claim to be numbered among the greatest personalities in the field of engineering and industry must not be sought there. One single achievement, however widely important, would never have satisfied his eager passion for work. His life was immeasurably richer than that of the great inventor in the ordinary acceptation of the word. He was undoubtedly the pioneer of a great technical idea, an idea which was his exclusive property, but technical progress in itself was not his first goal. His great claim to a fame that stretches beyond the Cast Steel Works, and beyond the present, rests on the fact that side by side with his enormous talents in his profession, he possessed a grandeur of conception in his enterprises, and a moral depth, such as have seldom been combined in one man's character.

Krupp's lasting merit as a technical worker is expressed trenchantly on the marble relief erected to him in the German Museum at Munich, by the Society of German Engineers. "By his iron perseverance, his ardent audacity and his creative mind, he has raised steel industry from the blacksmith's shop to the highest capability of production, to the honour and for the defence of his country." The Standard, after his death, said with laconic brevity:—"England is the land of iron, Krupp made the precious qualities of steel his domain." Such was the case. An idea of splendid simplicity and yet of revolutionary daring runs like a guiding clue through all Krupp's doings:—namely to present cast steel to the increasing demands of industry, as a material that meets every requirement, whether for hardness, purity or strength. It was to declare war on cast iron, forged iron, welded steel and at last on bronze, and this contest Alfred Krupp carried on with unceasing persistence from his 14th year to his old age. Not till then was the victory assured, and he speaks of it in his usual figurative manner:—"We are now living in the steel age. The railway system, the rise of Germany, the fall of France, all belong to the age of steel; the age of bronze is ended; bronze has ceased to be the material for war, henceforth it is destined for gentler uses." But it needed a lifetime to achieve this. It was the struggle of the new with the traditional, of home produce against foreign, of what was costly and excellent against what was cheap and inferior, a struggle which was rendered more difficult by the necessity of having to prove the superiority of cast steel by new inventions and applications in almost every new field he attacked, and then, after great outlay, to contend with the force of habit for twenty or thirty years, before the seed ripened to the harvest. Again and again Krupp experienced that it is easier to devise an improvement than to introduce it into use. It is true that almost all his attempts were crowned with success, but what an amount of work and self-renunciation preceded each of these successes, and how often his inventions sowed the seed for another's harvest. But he let nothing turn him from his path. The notion that cast steel, which had hitherto only been used for delicate tools, could be employed for heavy machinery, for rolls, axles, wheels and gun tubes, was so new and bold that at first it met with universal opposition. The good of such an invention was scarcely understood. Even men like Borsig, who did not deny the superiority of cast steel, considered the metals in ordinary use as sufficient, and disputed the necessity of so radical a change. Krupp alone looked ahead and saw how soon technical requirements would advance. He always anticipated these requirements. He furnished the mints with cast-steel dies, which did ten times the work of the former tools, he furnished goldsmiths with rolls which combined the greatest purity with indestructibility, drove the English chilled cast-iron rolls out of the field, and conquered the whole world; he gave machine builders the opportunity of uniting great strength with reduced weight, and he went further step by step. He increased the security of railway traffic by introducing cast steel into the construction of parts of engines, and by the weldless tyre, and so anticipated the increase in railway traffic. By the manufacture of heavy cast-steel shafting he enabled transatlantic steam navigation to increase its power and speed with complete security, and at a time when German ship yards were still in their infancy as compared with English ones, Krupp was furnishing steel shafts for the quickest English ocean steamers. His much-admired steel ingots, which grew in size from one exhibition to another, placed him in the van of the steel industry, and showed his determination to fulfil the most difficult tasks with the material he had placed at the service of engineering. From the construction of machinery, he made a bold step to the manufacture of ordnance. He created the steel gun tube, and began the contest with cast iron and bronze cannon which engaged him for nearly 30 years, and ended by securing the victory of cast steel, and the military supremacy of Germany. In order to prove the advantages of cast steel as gun metal, he was obliged to take up design in this branch too, and here again he was rewarded by unprecedented success. He made inventions and improvements in field guns, siege guns, and naval guns, and he carried out the designs of others without any jealousy.

The problems which occupied him could not all be solved in the field where he first began to work. The development of engineering, after 1860, took him far beyond the limitations of crucible steel. New refining processes were being invented, a revolution was taking place in the entire steel industry. Here again Krupp attacked the matter vigorously. He showed no jealousy in recognizing the value of other men's inventions, nor hesitation in adopting them. He was among the first to adopt the inventions of Bessemer, Martin and Siemens, and to place the great achievements of others side by side with his own. But he always filled what he adopted with his own spirit, and thus, when he introduced the Bessemer process, he created a home industry in steel rails, and kept the German railway system from again becoming dependent on England. By such a creative spirit he justified his adoption of the ideas and inventions of other men. Krupp acted in the domain of industry according to Goethe's words:—"All that exists in mine; the great matter is how to employ it." The invention itself was of less value in his eyes than the use which farsightedness and perseverance could make of it. He met the enthusiasm of inventors in his factory with cool reserve:—"More inventors," he would say, "have found their way from the first floor to the garret than vice versa." He expressly cautioned the engineers on his staff:—"You can't make an invention as you find a coin; you may be stimulated to invent something by an observation, an idea, a flash of thought, but as a rule any improvement or innovation worth speaking of absorbs an incalculable amount of time and money, because the difficult points only appear gradually. So let us leave inventing to other people. It is much better and cheaper to use other men's ideas, and to pay them their price." So much higher did he place work than invention,—the man of action, the creative economist than the technician. It was indeed the only way in which his many enterprises could succeed. The introduction of cast steel had an immense influence on the development of mechanics. Krupp accustomed industry to the use of his steel in large quantities, he taught foreign countries to respect and to purchase German manufactures on account of their superior quality. The employment of Krupp steel in English ocean steamers, French war ships, American mints, East-Indian locomotives, and Egyptian guns carried the fame of German industry all over the world at a time when Germany was despised for her lack of political unity. On the other hand, Krupp was the first to transplant the best French and English inventions in the steel industry on to German soil, and to secure for himself and his country an honourable place in the wider field of ingot-steel production.

At a time when the whole of Germany seemed to have a mania for company-making, Krupp steadfastly resisted all persuasions to make his works into a company, and he has furnished a proof that private enterprise, supported by honest work and foresight combined with organisation on a broad basis, can attain the highest success. He was, in fact, the first to create a vast self-contained industrial enterprise on a secure foundation independent of the fluctuations of the market. He provided his works with blast furnaces, iron ore mines and collieries, his steamers ploughed the seas, and his proving grounds—the biggest in the world—rendered the works independent of the slow process of official testing. The world at large was his sphere of action. He refused opportunities of developing his factory more rapidly abroad, and kept the best results of his energy for his native land. He created the German steel industry, he gave his country the weapon which decided the battle for their unity and greatness, and when the great war was finished, it was the latest desire of his life to watch that German ordnance did not deteriorate.

Thus he carried his undertakings to a height and importance, far beyond that of the life works of other kings of industry, but even that did not satisfy him. Just as every success was only an instrument in the service of his works, so his entire creation was only an instrument in the service of his great philanthropic ideas. The value of his works to his native land, nay, their very right to exist, stood or fell for him with the welfare of his workpeople, and seldom has a great industrialist spoken so proudly and with so much justification as he did when he said:—"Our workmen shall earn the maximum that industry can afford to pay, or we will give up an industry in which the men must starve." Knowing that even the highest wages did not ensure the wellbeing of the workpeople, he set up the comprehensive institutions for providing dwellings, supply stores and insurance which, as far as human power goes, make the lives of his men and their families comfortable as long as they continue to be loyal members of the Krupp community. — Here again Krupp took the lead, and set an example in the struggle with the social evils which accompanied the development of industry. His simple creed that an industrialist must keep his heart and his hand open to those who serve him, and the practical way in which he acted on it, has made itself felt far and wide; he set social legislation an example, which in spite of all detraction, will long be a blessing.

It cannot be doubted that his work embodied many precious aids to human progress. But that which places him highest, that which stamps his deeds with immortality, even when they were only concerned with the present, is the way in which he worked. His whole being was so permeated with unresting energy, that work was a delight and its own reward, thus he could wait long years without impatience for the harvest whose tardiness would have discouraged most men. "Stake the present on the future" was the motto which guided his life and actions. The things he undertook, were often dry and commonplace, and he set about them in a dry and matter-of-fact way. But their end and aim always shone with an ideal light, which illuminated and glorified his daily toil, made small things great, and gave monotony charm. This ideal conception attended his small doings as well as his great. Only when he thus fixed his eye on the goal could he venture on a great undertaking which he knew would at first involve him in heavy losses, and which could only bring in profit after years of waiting. His ventures had so little to do with selfish aims or greed of gain that he counted time and money as nothing for them. He well knew that his way of seeing could not always prevail. He said himself:—"I have my eye on the great goal, I must sacrifice everything to reach it. My successors will have to be more cautious, they will not be justified in making such sacrifices so lightly." But during his own lifetime, he considered himself bound by his responsibility even for goals that lay in the far distance. He was not daunted by the sure knowledge that he could not finish everything, that he must leave much to time, and that much of his work would bear no fruit for him. He kept his faith in the victory of the good cause, and bequeathed that faith to his successors:—an ideal and indestructible possession. Some of Alfred Krupp's achievements in technical engineering, some of his philanthropic works have been surpassed by the advance of civilisation and more perfect things have taken their place. But his greatness as a man secures him an immortal and honourable place in the annals of mankind, and raises him to a place among those rare souls, who in the words of the poet are:

"Von jener Jugend, die uns nie entfliegt,
"Von jenem Mut, der früher oder später
"Den Widerstand der stumpfen Welt besiegt,
"Von jenem Glauben, der sich stets erhöhter,
"Bald kühn hervordrängt, bald geduldig schmiegt,
"Damit das Gute wirke, wachse, fromme!"

# FRIEDRICH ALFRED KRUPP.

Friedrich Alfred Krupp was in his 34th year, when he succeeded to his father's property and became the sole head of the factory. For some years he had taken a share in the management, latterly as a member of the Procura. His father had trained him for his work, which means that he had learned from a teacher who was not easily pleased. And now he had to watch over the inheritance that had fallen to him, and to continue the great work in the spirit of its founder, as his father's last will and testament ordained. This was in itself no easy task, considering the extent and varied nature of the enterprise, but it was rendered doubly difficult for the successor of a man like Alfred Krupp, who by 60 years of incessant, laborious work, had raised the factory from its small beginnings to importance and renown, and whose genius had permeated the whole undertaking till he died. The loss of such a leader was almost irreparable, whoever his successor might be.

F. A. Krupp's active leadership of the works only lasted 15 years, but short as the time was, it sufficed for him to develope the factory along strongly marked lines. He certainly was not endowed with his father's genius, and he stood for many people as the sons of such men usually stand, in the shadow of his father's greatness;—his quiet, modest nature remaining unnoticed by the world. But all who shared in his life and work, who gauged the depths of his character, deeply mourned the early death of so noble and capable a man, and their hearts still glow and their eyes still moisten when his name is mentioned. We are not going to attempt to place Friedrich Alfred Krupp on a level with his father. But justice demands that we describe his character and his significance with sincerity, and that we allot to him the honourable place that belongs to him among those who bear the name of Krupp. He devoted himself to his duty with the loyalty that his father prized above everything, and he ruled his paternal inheritance with strength and circumspection. And his honest efforts did not fail of success. This is obvious from the fact that, by the year 1902, the number of those employed had risen from 20,000 to 43,000. It is true that Alfred Krupp's genius had sown many seeds for the further development of his enterprise, and its extension has been promoted by the progress of technic and industry in Germany since the middle of the 'nineties. But the success is, in the main, the result of the well-directed work done under F. A. Krupp's leadership. For the works were not only enlarged, but their productive capacity also attained a higher grade during that time. This applies to Krupp as the armourer of the empire, who was called upon to provide weapons of offence and defence for the Fleet which was then coming into being; it applies to the high place the Krupp works have always held in German steel industry, it applies to the articles for the world's market, a branch of production, for which the plans were made and the foundations laid at this time, so as to provide it with modern appliances on the broadest foundations. But Krupp did not consider his mission fulfilled by this important extension of the works; under his management new fields were opened up by the manufacture of armour plates, by the purchase of the Grusonwerk, by the acquisition and rebuilding of the Germaniawerft, where valuable services have since been rendered for the defence of Germany. Thus we may say that he not only was a faithful steward of his paternal inheritance, but that he guided it firmly onwards and upwards, and gained it anew by loyal devotion to the duties he had taken upon him.

Friedrich Alfred Krupp was born on the 17th of February 1854, in the little house in the works, which had been built in the 'forties, between the old home and the old foundry. His birth coincided with the first great advance of the factory, the fame of which had been established by the first London International Exhibition, a few years before. He was an only child. He was spared the privations and poverty with which his father had had to struggle so long, but another trouble clouded his childhood, and deprived him of youthful pleasures. He was delicate, and passed through several severe illnesses in his early years. Thus the battle of life began early for him too. His parents, in the hope of strengthening him, brought him up with almost Spartan simplicity, and accustomed him to a very regular mode of life. Their system included the regular practice of gymnastics, which he continued all his life. The importance he attached to all physical exercise when he was a man, came from this early acquaintance with their beneficial effects. This induced him in later years to introduce games and sports among his employees and in his native town. He was prevented by his delicacy from attending school regularly. At first he had lessons at home. When the family went to the little country-house at the Hügel, which his father had bought in 1862, he attended the second-grade school in the neighbouring town of Werden. In 1866 his schooling was interrupted by a long journey abroad, and when he came back he attended the grammar school at Essen, till another attack of rheumatic fever, which had troubled him before, put an end to his school days in 1870. This attack was unusually long and severe, for in May, 1871, Alfred Krupp wrote sorrowfully:—"I am still waiting for K's opinion as to Fritz's prospects:—if we may hope that he will entirely shake off the effects of this illness, which has lasted six months, if he will come back well from the baths he is taking, and most of all, if there is any likelihood of our hope being fulfilled of seeing him straight and strong, or if we must resign ourselves to giving up one hope or the other." The hope of his recovery was fulfilled, but for many years, the utmost care was necessary, and sojourns in watering-places and in the south were indispensable. As long as F. A. Krupp lived he felt the effects of this illness, which attacked him once more in the last year of his life. He frequently suffered from asthma and insomnia, and he began to stoop in early manhood. To his great regret he could not serve in the army. In 1877 he entered the 3rd Regiment of Baden Dragoons, No. 22, called Prince Carl, at Carlsruhe, to serve his year, but was dismissed after a few weeks, as unfit for service. This delicacy of health and the retired life it entailed, produced the shyness and extreme sensitiveness of mind and body of which his father often complained. The best means of counteracting these propensities would have been the companionship of lads of his own age, but this had to be restricted in consideration of his weak health, which often prevented his joining in their pursuits and games. He took a great deal of trouble to overcome his retiring disposition, which he acknowledged to be a weakness. "The struggle with my sensitiveness has been the hardest of my life." The following story told by one who had been a guest at the Hügel shows how seriously he took the matter. Krupp had taken this visitor to see the workmen's model dwellings, the Alfredshof, and had gone into one of the houses there, and had conversed pleasantly with the woman of the house for some little time. He afterwards told his guest that, at one time, it was absolutely impossible for him to enter into conversation with the people, and that he had only brought himself to do so by continuous practice, but that now he could do his duty in this respect as owner of the works. However, he always tried to avoid official functions, and he had no talent for public speaking. Nor could he ever shake off his sensitiveness to public criticism of his personal or business habits, though in such a position as his, a certain amount of indifference to such matters is very necessary.

Nor was Krupp's training for his future calling carried out on the usual lines. He had already in his early years shown a keen interest in natural science and technical matters, and his inclinations had been greatly fostered by repeated journeys in the company of his medical attendant; and, sensible of the gaps in his schooling, he cherished an ardent desire for thorough scientific and technical education. But his father would not hear a word on the subject. Alfred Krupp had firmly-rooted ideas of his own about his son's future duties, and of the best way of preparing him for them, and these ideas he insisted on, without any consideration for the lad's wishes. He wished to be his son's principal teacher himself, and if possible his only one. He had frequently made Fritz, both in boyhood and in youth, look at everything in the workshops. At the same time he had given him some light office-work. He now proceeded to hand over to his son the management of certain details of his own work. But no prominence was given to the technical side, he rather turned his son's attention to matters concerning the management, gave him authority and supervision in one department or another, made him the medium by which he transmitted his wishes and ideas to the Procura, in fact, sought to train him gradually to be his own personal assistant. It was, no doubt, in the first place Alfred Krupp's own failing health which caused him to initiate his son so early into business. The anxiety about the future of the works and those employed there, which took possession of him in his old age, urged him to take thought for the succession. Above all he wished to have the chance of judging whether or no his son could fill his place worthily and capably:—"I will convince myself by observation, during my lifetime, of what I hope and desire; namely that the probable inheritor of the works, besides possessing the necessary ability, is as thoroughly inspired with love of them and a sense of duty as is necessary to guarantee the well being of the establishment, with all the thousands it employs. If fate had been so hard as to deny me this, it would have been my duty to make other dispositions, so as to be sure of maintaining that which I have called into being." Besides this personal anxiety, Alfred Krupp had other weighty reasons for the manner in which he trained his son. It was perfectly clear that the way he —the creator of the works with his manifold talents and his intimate acquaintance with every detail—had conducted the management, would be no longer practicable in the future, it would not even be advisable. It was scarcely possible to give the future head of the factory a scientific training, which would include every subject the works combined:— such a training would have demanded years and years of study, or it would have been a "thing of shreds and patches", which might easily do more harm than good. It was not scientific study, but practical life which had given Alfred Krupp the technical training which was comprehensive enough to enable him to be the sole manager. Such knowledge and competence had now to be divided among many. What the factory really required from its next leader was a gift for organisation and a grip on the great problems of the future. It seemed more important that the future leader should have the talent of finding the right man for the right place and of trusting such a man with the widest possible scope for the use of his powers; more important in the great factory, with its many branches, that the harmonious co-operation of all should be aimed at, than that its head should have all the advantages of the usual scientific and technical training, which Alfred Krupp feared besides, might result in one-sidedness of knowledge and interests. Personal motives, arising from Alfred Krupp's character, played their part in the matter too. Convinced as he was, that he could, by his own method of instruction, obtain the best results, he neither could nor would give up to others the training of his son for the unique place he would one day fill. He wished to have the young man constantly near him, to initiate him thoroughly into his own principles, seeking thereby to fix a tradition for the management of the factory. He wished to be the one to develop and perfect his successor in all that seemed requisite to him for the future manager, according to the abundant experience of his own laborious life. Even the mistrust which so often clouded Alfred Krupp's declining years, had a part in these decisions. The more closely he linked his son to himself the more completely he hoped to withdraw him from all external or distracting influence, and to keep him entirely within his own range of ideas.

Such a method of education must inevitably have often jarred with Fritz's wishes and inclinations, but the relations between father and son were, on the whole, never disturbed by it. And the events of 1874 drew the two much nearer together in the works, and in their anxiety about the future. Friedrich Alfred was deeply moved by his father's intense grief when all that he had created out of nothing was tottering around him. Then it was that Alfred Krupp sought and found in his son the confidant on whom he could lean unreservedly, and to whom he could impart his inmost thoughts. It was with a heavy heart, that in the autumn of that year, he was obliged to send his son, who had again been ill, to Egypt for his health. He continued his educational system in a series of admirable letters, to which the approaching majority of his son gave special importance. "The 17th of February is now drawing near, the day when you will come of age, and enter on a position of unusual privileges and duties. May God's grace strengthen you for both." He was never weary of insisting on the great responsibilities which lay before his son. "Besides yourself to answer for, there is the factory with its many thousands of families, their welfare is dependent on your own conduct and welfare." Alfred Krupp's terrible agitation over the events of the previous year still vibrates in these letters, events which were "without any precedent in his whole past" and which "had brought him nigh to shipwreck". He speaks of the principles to which he owed all his successes, and sternly condemns every departure from them, all offences against order and duty, all inclination to self-will and indolence, as the causes of the ruinous state of things. The bitter words:—"My old idea that loyalty was universal, turns out to be an illusion," reveal one of the sources of the mistrust that troubled Alfred Krupp in his old age. With confiding frankness, he pointed out to his son the errors in the management at that time, and connected them with the claims which the future of the works had a right to make on their owner:—"Strict caution in the choice of your friends, insight into all transactions, work, and general aspect of things, with a view to future development, and command of the great whole, and an eye fixed on possible expansion and duration." "There will be great demands made on your knowledge; any way, it must be great enough to enable you to judge the knowledge and abilities of those whom you have to employ and remunerate." "You must be thoroughly versed in all matters of finance, reckoning and calculation. No one must be able to 'pass you off on *x* for a *u*'. That alone can secure you against the evil of which I am warning you, namely, that others, by selfishness and intrigue, might usurp your prerogatives and powers." Side by side with these lofty expectations, we discern a hope that his son will prove worthy of his great calling. "Your progressive development ever strengthens my certitude, the faith in you that I shall need till my last hour, my belief that you are equal to the position allotted to you, and that you will fulfil your duties gladly." He awaited Fritz's return with eagerness, and expressed the intention of then giving him "the central position in the management", which was needed "to prepare you for the time when you will have to take my place, and decide matters in my stead". Such a position would have accorded with Fritz's wishes and character, but here again his hopes were disappointed. His father, it is true gave him a fixed salary after his return from Egypt, but his work remained much the same as before. Whether it was the old dread of giving a one-sided direction to Fritz's training, by putting him into a leading position, whether it was anxiety for a homogeneous management of the factory, which deterred him from giving his son a prominent, independent place, does not matter, whichever it was, Friedrich Alfred remained for a considerable time in his former position of his father's confidant and chief assistant. He was frequently entrusted with journeys, which gave him an opportunity of representing the interests of the works abroad. And during this close community of work Alfred Krupp continued to gain the conviction he desired, that in future the factory would not lack a capable head, who would be fully equal to the task of managing it.

Friedrich Alfred Krupp's position as intermediary between his father and the management was by no means an easy one, and for much of the business that fell to his share he was too young. So in his professional life, too, he had to pass through the hard school of self-renunciation. Though he always looked up with reverence to his father as the perfect type of faithfulness to duty and unwearying activity, still his own development was somewhat repressed by this overmastering personality. The disadvantage was increased by the moods of his father's old age, by the inner discord, which made it impossible for him in spite of all his love for and trust in his son, to cede to him the desired equality with himself. Therefore the work that fell to the son's share required an immense amount of tact, adroitness and disinterestedness, both as regarded his conduct to his aging father, and his position to those below him, who were employed in the factory. The outcome of these trials was, however, of great value to him in his subsequent work. And though during this schooling he had not infrequently suffered from his father's peculiarities, no bitterness was stirred in him, and he was rather fond of remembering this period of his life, which he called his apprenticeship. "In so large a concern occasional friction between some links of the mighty chain is inevitable, and such friction can only occasion no damage to the whole, when the leader knows how to smooth it out.—I learnt that at the time when I myself was an ordinary link in the great chain, and had personal experience of the feelings of an official," he used to say and then add with a knowing smile:—"Nothing does a man so much good, as when for a time things do not go according to his wishes." Friedrich Alfred Krupp was at that time not only in constant touch with the business management, but also with the workshops. In his boyhood and youth his father had often taken him round, introduced him to the older foremen, and incited him to get a comprehensive view of the whole thing by working practically himself. "If you want explanations, you have only to ask the old foremen," he said to him more than once. So young Krupp came into contact early with all ranks of those employed in the works. He and the men got to know one another, and the foundations were laid of the great personal influence which Friedrich Alfred Krupp exercised later as head of the works. But he saw the factory with eyes different from his father's. At an age when one is most of all receptive for impressions he lived through the years of their most brilliant development, of their growing importance in national industry and national defence; the impression these years left on him was necessarily imperishable. He passed from youth to manhood amid far other surroundings than his father's had been, and he learnt from the first to see the whole undertaking in a wider perspective and with a broader glance than the father, who had worked at petty details and had, so to say, created the whole out of nothing by the labour of his hands. For Alfred Krupp, as long as he lived, the stern claims of service, duty and practical work remained absolutely binding. With the son it was otherwise; his view of science and investigation was less prejudiced than his father's, and he had a less one-sided opinion in other matters which lay outside the stern daily duties. This can be seen, for instance, in his conception of what should be done to promote the welfare of his people; in this, while he did not overlook their pressing needs, he turned his attention more liberally than his father had done to providing for recreation, sports, entertainment and mental culture. He saw clearly that the modern development of technic and of social conditions imposes an ever-increasing strain on the powers of every worker, and that this strain must be, to some extent counteracted by allowing personal inclinations and tastes to have their turn.

Until the beginning of the 'eighties Friedrich Alfred Krupp rarely had the opportunity of taking part in the technical details of the factory. He had always resented this exclusion from the fundamental part of the work and now, without any special authorisation from his father, he began to work of his own accord in this field. He specially took up chemical and metallurgical problems. These serious efforts brought about the fulfilment of his wish, for at the beginning of 1882, he got permission to go to the Polytechnical Institute at Brunswick to study natural science, particularly chemistry. His stay there was only of short duration, but treatises, written at the time, still exist, which not only prove that Friedrich Alfred Krupp studied seriously, but also that he penetrated pretty deeply into scientific questions, and endeavoured to solve them by practical experiments. He availed himself of the personal connexions he had formed in Brunswick later on, when scientific methods, especially in the treatment of metallurgical problems, obtained more in the factory. He succeeded in so completely gaining his father's interest in the matter, that the latter, to the amazement of many in the works, declared it necessary to engage a noted specialist to make experiments in purely scientific matters. In the following years an institution now immensely enlarged and known as the "Institute for chemical and physical experiments" was founded.

The year 1882 saw the fulfilment of another of young Krupp's wishes. On the occasion of his betrothal his father, as a visible token of his confidence in his son, gave him a share in the management, by making him a member of the Procura. This at length gave Fritz the complete right to take his share, without any special authorisation, in all important discussions and decisions, so now he could get a comprehensive insight into the whole work of the factory. He consequently took a regular part in the consultations as to re-constituting and cheapening the cost of production in the Bessemer and rail-rolling works, problems that were zealously studied about the middle of the 'eighties. He devoted his attention specially to metallurgical questions, continuing with great interest the studies that he had engaged in at Brunswick. And at length, he took the place of his father, who seldom came to the works in his latter years, also in those branches of the work which especially occupied Alfred Krupp's mind at this time, principally the armour experiments. He also had to represent his father more and more in the ever increasing official functions, sometimes in Essen, sometimes at a distance. It was but natural that, in this official capacity, he needed even more than ever tact and fine feeling in his way of treating people if he desired to make himself useful to the factory. Fortunately nature had endowed him with these qualities. He spared his father's feelings as much as possible by keeping his own personality in the background, but on the whole, his influence was perceptible in conciliating and smoothing over the difficulties of those days.

In the autumn of the same year, Friedrich Alfred Krupp married Margarethe, Baroness von Ende, a daughter of the Provincial President at Cassel, who had become very friendly at the Hügel, while he was District President at Düsseldorf. The young couple went to live first in the Garden House in the factory, later on they removed to the small house at the Hügel, which till then had been used for the reception of guests; it is at present the residence of Friedrich Alfred Krupp's widow. Of this marriage two daughters were born:—Bertha, to whom on her father's death, by the provisions of her grandfather's will, the works passed—was born during Alfred Krupp's life, on the 29th of March 1886, and the younger, Barbara, on the 25th of September 1887.

After the death of his father, which was followed a year later by that of his mother, Friedrich Alfred Krupp became the real head of the works, which he continued to manage on the same lines as his father, namely as the personally responsible owner of a private enterprise. He established his private offices in the old family home, which he cherished with the same filial piety as his father had done. There he attended to the directors' reports, decided weighty matters, and settled most of the business transactions that brought him into contact with his employees. He moved out of the small house at the Hügel into the large one which his father had occupied. Friedrich Alfred Krupp was warmly attached to this property, and he took every opportunity offered, by alterations and enlargements, to complete and embellish it with his own genuinely artistic taste. Here, with the valuable assistance of his wife, he fulfilled the traditional duties of reception and hospitality on a very large scale. Except when he was travelling, a day seldom passed on which guests—sometimes in great numbers—were not received at the Hügel. He was always a courteous and aimable host, though his natural disposition made this part of his duties somewhat onerous:—he only felt really at home in a small circle of intimate friends. In comparison with old days, the circle of visitors had greatly extended, and now among the guests of the firm and the friends of the family, the representatives of art and science were often met with. The friendships which Alfred Krupp had formed, and which were, so to speak, part and parcel of the Hügel society, were kept up by the son, who had also by his simple, kindly disposition made a number of new friends. He too, like his father, had the good fortune to gain the confidence and esteem of his sovereign in a very high degree. William II, as the father of his people, always took an interest in the works. He called their owner his friend, and was a frequent guest at the Hügel. He also showed his esteem for F. A. Krupp by nominating him to a place in the Prussian State Council and in the Upper House.

A great number of honours and distinctions were conferred on F. A. Krupp. His mind was far too simple to desire such marks of honour, and when, in spite of himself, he accepted them, it was as the representative of the works; he considered them in the first place, as a recognition of the faithful services of his fellow workers. He said this publicly when he was one of the first on whom the Polytechnical College at Aix-la-chapelle conferred the honorary degree of Doctor of Engineering. And when he accepted the dignity of Privy Councillor with the title of "Exzellenz", he expressed his wish in the works that he should still be addressed by his name only. Again, when the offer of raising him to the nobility was made, he declined it, saying "he had no desire to bear any name but his father's".

A new duty was laid on Krupp's shoulders when he was elected to the German Reichstag for the constituency of Essen, in 1893. It was the time of angry debate about the Army Bill, and though Krupp was aware that he had little inclination or ability for parliamentary life, he accepted the candidature, as there was a probability that his personality would carry weight. His membership continued till 1898. During these years he moved to Berlin for the sessions of the Reichstag, attended regularly, and gave much detailed study to all the important questions which were then under discussion. He fulfilled all his duties as a member conscientiously and zealously, but he never attempted to make a speech, for he did not possess the gift of extempore eloquence. Even during these residences in Berlin, he kept the management of the works in his own hands, although the course of business in Essen was not rendered easier by absences of the chief, which sometimes lasted for months. His entry into political life raised much personal hostility against him, and heightened the opposition which had already been aroused by the steadfast position he and the managers of the factory had taken with regard to all questions touching the relations between employers and employed. From the first the Krupp works and their owner had been held by their opponents to be the very stronghold and embodiment of "capitalism" in production, and unfortunately, as time went an, the strife became so bitter that the Social Democrats who were growing ever bolder and more unsparing in their attacks, carried the fight from political to personal matters, and resorted to the weapons of calumny and libel.

During the last years of his life, Krupp's health, which for some time had been tolerably good, became less satisfactory. He was, in fact, not fully equal to the exertions which were necessary in the fulfilment of his manifold duties. The long winters, too, which he had spent in Berlin, while a member of the Reichstag, had been anything but beneficial to him. Once again the old malady asserted itself. In the winter of 1898/99 he was obliged to seek a warmer climate and he spent several months in the Isle of Capri. As the climate of the island did him much good, he passed the winter months there regularly for the next few years. He employed his leisure in deep-sea investigation and research, a subject which had exited his interest formerly. He pursued these investigations scientifically, at first with simple means, and later on a much larger scale with a steamyacht of his own. The results were published after his death by a member of the Zoological Society at Naples.

In spite of all the work and responsibility which his profession imposed upon him, Krupp had always retained his old affection for pursuits of this kind, indeed for everything to do with scientific subjects. In following out these various interests, he always tried, even when he had reached manhood, to extend his knowledge and to fill the gaps left by the abrupt end of his school days, and the peculiar nature of his professional training. The perception that some things had been neglected, only quickened his zeal, and the many journeys he had made had been of great help to him. Natural science, especially, had early laid its spell upon him. His studies, which had at first been limited to metallurgy, and its basis in chemistry and physics, were extended as time went on. The wealth of the Essen formation in fossils encouraged him to work at geology and palaeontology. He began to form a collection at Hügel which was enlarged by the results of his biological researches, and still more by those he made in deep-sea life, till it finally formed a natural history cabinet of considerable value. He was not only a collector, but tried also to master the details of arranging, classifying and working with the microscope. Nor was he a mere looker-on in his deep-sea researches, for he shared actively in every necessary part of the scientist's work. A number of scientific publications and institutions owe their origin to his stimulus and support. At the end of the 'nineties, he began to compile for his own use, a lexion of technical zoological terms, which, however, soon reached such a size, that the continuation of it had to be handed over to professionals. It was finished long after his death, and published under the title of "Zoological Lexicon." About the same time he started a discussion on a subject which throws light on his ideas as to the close affinity between the laws of natural and social life. In studying the theory of the origin of species, the question had occurred to him whether it were not applicable in a certain sense, to the inner development of politics and thereby to the legislation of states. He communicated his ideas to professors of the subject, and suggested that a prize should be offered for the best essay on the theme. He himself provided the money for the purpose. He kept himself in the background all through, and he did not live to see the valuable result of the idea, which was a work entitled "Nature and State," containing a collection of the best essays sent in on the subject. Among the scientific institutions which he furthered we may mention:—the excavations in Egypt, the German Oriental Society, the Physiological Institute in the Zoological Station at Naples, the Biological Station at Plön, the Neurobiological Institute in Berlin. He always made it a condition that his name should not appear, and it was only after his death that the world gradually learnt the extent of his liberality in this direction.

The encouragement he gave to the fine arts was much more direct and considerable. The town of Essen especially owes him much in this respect. The Musical Society, the theatre, the town orchestra, the Saalbau, and the Museum of Fine Arts all shared his beneficence. He considered these benefits conferred on the town, as a completion of the institutions for the welfare of the factory. He did not, however, confine himself to these narrow limits, but was always ready to contribute to such objects on a wider field. He appreciated and patronized every branch of art. Architecture, painting and sculpture claimed his warm interest, and his judgement, in painting especially, was intelligent and independent. He bought many works of art, selecting them not only for the sake of the artist's name and fame, but because he set an unbiassed value upon them. In the collection of pictures at the Hügel, there are many early works of artists whose subsequent fame has confirmed Krupp's opinion. He promoted art, too, by granting to many young men of talent the means of artistic training, and though he was sometimes disappointed in the recipients of his bounty, he was not deterred by this from extending his help to others. He resembled his father and grandfather in his love of building, and he was enough of an architect to give valuable suggestions, when new buildings were being designed. It is mainly attributable to him that those Krupp workmen's colonies which were erected in his time, show an improvement not only in their practical construction, but also in their comfort and beauty, they have, indeed, set an example for such enterprises. He thoroughly grasped the importance of the home environment in developing the minds and spirits of the people. He also endeavoured to improve the interior arrangement of the workmen's dwellings. When the first Krupp lodging house for bachelors was built, he himself designed and drafted part of the interior fittings. In 1901, he started the idea of a competition in making plans for beautiful and simple model interiors for workmen's dwellings. This idea was put into execution with the assistance of the Rhenish Society for the Betterment of Workmen's Dwellings; two of the prize designs were afterwards carried out and used in fitting up the Krupp model dwelling exhibited at Düsseldorf in 1902.

We have already said that much of Friedrich Alfred Krupp's personal influence in the factory was based on his purely human qualities. He resembled his father neither in outward appearance, nor in his manner of behaviour and acting; still many traits of his character were evidently inherited from his father. His disposition was sincere and noble, his manners plain and simple. Though surrounded by all that wealth can give, he had a horror of ostentation. He was absolutely free from self-conceit, and knew nothing of pride and ambition except in things relating to the prosperity or the products of his works. In personal intercourse he showed an unaffected modesty; it was said of him as a child:—"His kindliness and gratitude were touching, and he loved to give pleasure to his acquaintances by making little presents. He never ordered the servants about, but always begged of them what he wanted in a kindly way." This was something more than the pretty way of a nicely-behaved child; it sprang from the kind-heartedness, which was and remained the ruling trait of his character and which, coupled with his unassuming pleasant manners, opened all hearts to him later on. Throughout his life his was an infinitely grateful character, both in word and deed. He was always prompt with thanks for the smallest service done for him, for trifling marks of attention, which others consider as naturally due to their position, and his thanks were uttered with such genuine heartiness that they gave twofold pleasure. This trait was specially shown in his conduct to inferiors or servants, both at the Hügel and at the factory, by his care for them and his readiness to help them. So Krupp, side by side with the general provision for his people's welfare, exercised a personal influence, striving to work as a link in the great chain himself, and thus to pay a part of his debt of gratitude to his fellow workers. But, as in the case of his general interests, so in his kindness and readiness to help, he went far beyond his immediate surroundings and his own factory. It was a necessity of his nature to do good and give pleasure, and whenever he conscientiously could, he alleviated poverty and trouble. His native town, Essen, experienced this especially, for his purse was always open when appeals were made to him for public objects. Indeed there was scarcely one great undertaking of the kind in the whole country which claimed his help in vain.

This strongly-marked humaneness in Friedrich Alfred Krupp's character gave a peculiarly personal stamp to his relations to his fellow workers. He possessed a charm of manner, which made it easy even for new comers to feel at home in the Krupp circle. A friendly and confidential tone dominated in business as well as in social intercourse. Being entirely free from all pettiness of feeling Krupp could bear contradiction without showing irritation; he demanded the same from his staff in their dealings with one another, and a kindly glance from his eye was sufficient to enforce the demand and to repress all personal ill-feeling. Thus friendly co-operation was greatly promoted. It was pleasant to work with Krupp, for he examined the suggestions of his assistants carefully and thoroughly, when he was once convinced that they were made from good motives. It gave him real pleasure when he could bestow recognition on what others had done. When he had once honoured a man by his confidence he set no limits to its extent. Though this side of his character sometimes led him into mistakes, still it was one of the most powerful means by which Krupp gained the affection of men of great abilities and incited them to unselfish work for his cause. His personal influence was not confined to the higher officials, but was extended much further and exercised its charm on all ranks of the employees. His character was a strong bond for the cohesion of the whole, for the unity needful in such a big, many-sided work, and this uniting strength was the best quality that F. A. Krupp, as the head of the factory, could bestow on it. After Alfred Krupp's death the works stood greatly in need of such a uniting force and it proved one of the best influences in promoting their development, during the next fifteen years.

With all his kindliness and amiability, Krupp was by no means weak or irresolute. It is true, he did not possess his father's strength of mind, but his character was independent and his will firm. This was specially observable in his conduct towards his Board of Directors, where he preserved his independence of opinion and freedom of decision under all circumstances. He refrained from interference in details of business, for he was convinced of the necessity of a properly graduated order in the responsibility imposed on each man. He thus made it easier for his co-workers to fulfil their duties, and it was his constant endeavour to uphold the authority of the Board of Directors both in the works and outside them. But in all relating to his own position as head of the factory, he insisted on absolute independence; and never yielded to another any duty or privilege which belonged to him as his father's heir. Thus when the General Rules and Regulations were being revised, he steadily refused to admit any clause, which might trammel the future owner of the firm in the free exercise of his judgement. He reserved to himself the final decision in all weighty questions concerning the management on the general condition of the business, or such as were of importance to the development of the works, and he did not shrink from taking the responsibility of such decision on himself. With his lofty conception of his calling and profession he could not have entertained the thought that others were managing the works in his name, and deciding weighty questions for him.

He showed the same sense of duty in the position he assumed toward economical and social questions in general. He did not allow his gratitude to those he employed, nor his great kindness of heart to betray him into extravagant courses. Both in the application of these questions to the factory and to home industry in general, he always kept on firm ground, and preserved a clear practical view of the matter. For instance in writing about the relations between employer and employed he says:—"Everything must be done so that the difference shall not be increased. The real contest lies rather between the efforts of master and men on the one side, and competition on the other. The healthy development of home industry and of normal conditions for workmen must be sought rather in this peaceful strife, than in setting up differences between capital and employers on one side and workmen on the other. The prosperity of any branch of industry is a profit for the men. The interests of masters and men are identical. Competition in the various branches of industry fixes the maximum wage which a master can give, consistently with holding his own against competition." In holding such a creed, he was a true follower of his father. He required that the individual should be subordinate to the whole. He valued order and discipline as indispensable conditions, first for the harmonious co-operation of all, and thus for the prosperity of the whole. He would not allow that the authority of a responsible head of a work could be attacked. He would rather have resigned his position, than submit to anything that weakened it. He knew what German industry and Germany expected from him, the greatest German industrialist, and he stood manfully to his standard. When at the beginning of the 'nineties a tendency began to gain ground in government circles, which must finally, by its influence on legislation, have checked all friendly co-operation of employers and employed, and thus have undermined the very foundation and progress of home industry, he unhesitatingly took on himself the duty of protesting against it sternly and resolutely, in the higest quarters.

During his whole life's work, whether in developing what was already in existence or in opening up new ways, Friedrich Alfred Krupp held fast by the tradition established by his father. He certainly had no compunction in breaking an old custom, when altered circumstances made it desirable to do so; but he went about such innovations cautiously, as he knew the value of old established precedents in a great concern. Thus he made use of his father's experience even when he had to depart from his ways. He looked at such matters with the eye of a natural philosopher, recognizing the law of development in the factory as well as in nature. He did not see in progress a new thing,—a leap forwards,—but the gradual development of existing things which have been slowly growing. This was an all-important side of his character, and which greatly contributed to keep the works from over-hasty and spasmodic development after his father's death. Above all he never lost sight of his father's conception of the position the owner holds in the community of his works, of his duties and responsibilities to those he employs, and of his obligation to provide for the welfare of every member of the community. He, like his father, strove for the common good, and he put his feelings into deeds in proportion to the ever-increasing profits made by the factory. When he was head of the works many additions were made to his father's institutions for the welfare of the people; they were extended in many ways, especially in provisions for mental culture and bodily recreation. He gave, by his personal aid and advice, a special stamp to the buildings erected for these purposes, and whereas, in the older buildings, only the necessary and useful was aimed at, now beauty claims a place. Thus Krupp's honest endeavours in great things and small helped to maintain the mutual bond in the community of the works, though with the ever-increasing extension this became more and more difficult. The same feeling dictated the words he addressed to the workpeople at the unveiling of his father's monument. He declared it to be a testimony of the warm relations between master and men, an imperishable memorial of rare loyalty and attachment on the part of those employed in the factory. "May it," he continued, "be a means of strengthening the sentiment of mutual esteem and interdependence between employer and employed in every circle far and near——I, for my part, will always hold it my sacred duty to requite loyalty with loyalty."

With regard to the products of the factory, he kept to the long approved principle that only the very best should be delivered by the firm, and in order to maintain the producing power at the level required for this, he never hesitated to devote the profits in the first place, to the betterment of the works, the needs of which were more important to him than anything else. The financial regulations of the firm owe their clearly defined tradition to him. He considered the soundness and security of the finances, which guaranteed complete independence, as a primary condition for the permanent prosperity of the factory. The experiences of 1874, and the admonitions of his father had made a deep impression on him, and he strictly insisted on this principle. In every new undertaking which entailed considerable outlay he had the financial outlook most carefully examined and when necessary, extraordinary measures were adopted, as for instance is shown by the loans raised when the Grusonwerk was acquired in 1893, and the Germaniawerft in 1901. Indeed F. A. Krupp combined practical good sense and the insight of an organiser. The ruling lines of his conduct as the head of the whole, were: to distinguish between essentials and non-essentials, to abstain from pettiness, to act from a lofty standpoint, to choose the right men and put them in the right places, and to discover and maintain the conditions under which healthy co-operation of all concerned in the great whole was possible; and from these rules he would not be turned aside. And that his conception of his duty was right is proved by the fact, that after the death of a man of such mark as his father, no difficulties arose, that the centrifugal force, which naturally always exists in so great an organism, never prevailed, and that the development of the factory continued to follow its uniform and constant way.

Friedrich Alfred Krupp, though not the practised technician that his father was, possessed enough interest in, and comprehension of certain technical matters to further the development of the works in this field, too, in an important degree. He always found time for such matters, however much his attention was claimed by the duties of general management and by social functions. He required, first and foremost, as his parents had done, that the solid foundations of the works should be secured by the reputation and excellence of the products. He required that the factory should be so equipped that it might respond to all the needs and demands of his native country, and he gladly availed himself of an occasional opportunity to convince himself that nothing was neglected to this end. The wish of his heart was to effect the development of his factory into thoroughly modern steel works. He had shared in the preparatory steps taken in this direction during his father's lifetime, and since then he had never lost sight of the matter. His special plan was to erect plant for producing ingot steel on the most modern principles. Only a part of the plans for this project were carried out during his lifetime, because there-building of the Germaniawerft absorbed for a considerable time all the resources of the firm. But as soon as this undertaking was completed, Krupp insisted on the continuation of the buildings at Rheinhausen, and in the summer of 1902 the final plans for the new steel works and rolling mills were decided on and authorised by him. But over and above this improvement of the factory on the technical side, Krupp's value to the work rests on the combination of circumspection, foresight and resolution which he displayed as a manager and as a man of business. On the one hand, we have the steady development along uniform lines; Krupp allowed nothing that had once been attained to suffer neglect, while at the same time he would check a one-sided, unhealthy progress. On the other hand, a certain grandeur is unmistakably evident in his business policy. He was a man who not only enlarged that which already existed, but who set himself new important tasks. He approached great projects with confidence and courage, and, if they appealed to his judgement after the necessary investigation, he entered upon them with resolution and perseverance. The prime object of his work was not the need of the moment, but the future, which he always tried to make sure of by constant improvement.

He earnestly endeavoured by his last will to secure this future, and with it the welfare of all concerned in the works. His father's will had determined the succession to the factory. Friedrich Alfred Krupp adopted his father's ideas, and on his own part provided by testamentary dispositions that no difficulties or differences of opinion should arise after his death, out of the provisions of that will. He thought and acted without any sentimentality:—"Without considering any living person, one must, in these matters, take account of every contingency, and make one's dispositions accordingly." He even took into account that he might die early, and that the works become the property of a minor. The difficulties which might arise if the management were in the hands of guardians of such a minor, caused him to require that, in such a case, the concern should be converted into a limited company. He had the whole question carefully studied, and all suggestions thoroughly weighed for a contingency which unhappily occurred too soon. And what a good thing the making of this provision was, which—when the transformation took place in 1903—gave his family the certitude that they were acting in perfect conformity with the wishes of the deceased.

During the last year of his life, the Düsseldorf Industrial Exhibition took place, that great review of Rheno-Westphalian industry which gave to the world such a brilliant picture of Germany's efficiency in arts, crafts and science. The Krupp firm, as in the previous case of the Chicago Exhibition, did not expect to derive any commercial advantages from this exhibition; nevertheless, in recognition of its general significance for the nation, Krupp decided to exhibit very largely. He took a keen interest in the Exhibition, visiting it several times so as to study it in detail, little thinking that his participation in this undertaking was to be the end of his work on earth. But it was ordained that the exhibits of the firm at Düsseldorf were to be the last record of the productive power attained by the factory and of the philanthropic work done in the time, and under the name of Friedrich Alfred Krupp.

On the 22nd of November 1902, in the midst of projects and preparations for the building of the Rheinhausen works, Friedrich Alfred Krupp was suddenly struck down by death. The grief for his early death was very great both in the works and among those who knew him well; the universal sympathy which was felt and expressed was intensified by the tragic circumstances which attended his last illness and death. The German Emperor, in his telegram of condolence to the Board of Directors, honoured the dead man with the words:—"Providence placed Privy Councillor Krupp at the head of an undertaking which is known and respected far beyond the boundaries of our country. He considered it his mission in life, not only to preserve the work as his great father had left it to him, but to extend its fame ever further. His name is indissolubly linked with the development of iron industry, with the whole of armament, modern fortification and shipbuilding. In his care for his people, he was exemplary and unrivalled. Therefore I, to whom the departed was loyally devoted in the most patriotic sense, most deeply share his loss with his staff and his thousands of workpeople."

During the night of the 25th to the 26th of November the mortal remains of Friedrich Alfred Krupp were taken to the works, and laid in state in the room in the old house where he used to work. Thence on the morning of the 26th, he was carried to his grave, in the little churchyard in the midst of his native town, to be laid to his last rest by the side of his parents. The Emperor William II. who had chivalrously hastened to show to his friend the last honours, and as head of the German Empire, to hold his shield over the house and the memory of the departed, was the chief mourner. On the 7th of December, the staff and the workmen of the factory, to the number of 23,000, assembled in the vast dimly-lighted hall of the cast-steel foundry. On this historical ground, where once the first building of the Cast Steel Works and the house where later on F. A. Krupp was born, had stood, a memorial service which none present will ever forget, was held for the chief who had gone to his long rest. A desire was soon expressed in the factory to raise a worthy monument to their departed chief. His native town, Essen, which had once conferred on him the freedom of the city, and a number of friends, joined in the wish, and on the 17th of November 1907, the monument was unveiled. It stands in the "Limbecker Platz", not far from the entrance to the works, bearing eloquent witness to the gratitude and esteem which F. A. Krupp had won among those who belonged to him, by his life of work, love and loyalty. A plain stone covers his grave, on which are graven the words:—The memory of the just is blessed.

## THE CAST STEEL WORKS FROM 1887 TO 1902.

When Friedrich Alfred Krupp, at the age of 20 or thereabouts, was introduced into the various workshops of the Cast Steel Works, with his father's approval, the importance given to scientific work in metallurgy had greatly increased in comparison with former times. Alfred Krupp, like his father, had grown up without any profound knowledge of chemical and physical science; he had achieved his successes by purely empirical methods during half a century of work. But he was sufficiently liberal in his ideas to recognise the value of more modern scientific resources. From the time that the puddling and Bessemer processes had been introduced, accurate testings had gradually taken the place of the earlier way of judging steel by the appearance of the fracture, and its resistance to simple tests of bending, forging and hardening. The manager of the puddling shop arranged the first little laboratory for more accurate physical testing for his own use, and at his instigation the first chemist was appointed at the Cast Steel Works in 1863. The following year a special chemical laboratory was built in the Hügelstrasse, and Dr. Otto, professor of chemistry at the Brunswick Polytechnical School was asked to give advice in equipping it. These small testing rooms were the first step to the present chemical laboratory of the Cast Steel Works, which was moved into the large new building of the Institution for Chemical and Physical Experiments erected in 1909. Some idea of the increase of work done in the laboratory may best be given by the number of analyses made, which rose from 12,000 in 1889, to about 500,000 in 1911. The mechanical testing of steel had also begun early. The foundation of the mechanical testing shop at the Cast Steel Works was laid in 1862, by the purchase of the previously mentioned first machine for tensile tests, which had attracted much attention at the London International Exhibition. It was not, however, till the 'seventies that the testing department got its own shops and worked regularly. But the constantly increasing number of testings that had to be made, not only for the workshops, but also at the request of various customers, rendered the space alloted to the testing department too small as time advanced, and in 1901 a new building with the most modern appliances for testing was erected in the Frohnhauserstrasse. There were more than 108,000 mechanical tests made there in 1911.

With the introduction of the Siemens regenerator furnace, and the open-hearth process, the number of ironmasters who were scientifically trained became greater than before, and so F. A. Krupp, whose interest in this kind of study had always been keen, made acquaintance with the shops under a totally different aspect from that under which his father had found them long before. His own character, his love of science, his bent for going deep into one subject rather than taking up many subjects, were in harmony with the modern tendencies which he saw developing; it is true, this led him sometimes to occupy himself with details which, in his father's eyes, had nothing whatever to do with his practical studies, and were more likely to divide his attention from the one great aim, that of obtaining a clear perception of the whole, unobstructed by details. F. A. Krupp's first independent studies were made about the middle of the 'seventies and were directed to the employment of liquid carbonic acid, which had lately been produced successfully in large quantities, in various ways in the factory. Krupp tried it for cooling gun tubes, in taking off shrunk-on hoops, and especially for the condensation of steel castings. Experiments to produce a denser texture in steel castings, by employing various gases at high pressure in the moulds, had been begun in England by W. Siemens, F. A. Krupp adopted the idea in combination with his experiments in liquid carbonic acid, and by his persevering pursuit of the subject, in which he interested the engineers, he obtained lasting results to the benefit of the Cast Steel Works. His experiments brought him into contact with various physicists and chemists from other parts, and actually aroused a considerable degree of interest in his father, who used to call liquid carbonic acid "his son's adopted child", and also made several suggestions for its employment in the Cast Steel Works. Although the production of dense castings did not succeed in the way at first aimed at, the question continued to be discussed, with F. A. Krupp's active aid, until at last success was attained by a suitable adaptation of the moulds, which made it possible to cool the molten steel regularly according to fixed rules, and both to bring the density of the casting to the desired pitch and to avoid the formation of blow holes entirely. This was an object for which many had striven, and which Alfred Krupp's brother, Friedrich, thought be had actually reached in the 'forties; but his was mere momentary or accidental success, which did not bear the test of repetition. Now at last there was certain permanent success, which made the production of the largest steel ingots thoroughly uniform, and free from blow holes possible, and thereby gave the firm a great advantage over all other steel producing works.

The scope of F. A. Krupp's scientific interests was greatly extended by this work. He spent the winter of 1881/82 in Brunswick pursuing studies connected with his experiments in carbonic acid, and then matriculated there, in the following summer, at the Ducal Polytechnical School. Though his stay there was short, he brought back to the factory a keener interest in the adoption of exacter methods. The establishment of a second chemical laboratory in 1883 for purely scientific research was in a great measure due to his initiative. As the aim of such an institution he emphasized:—"Studies to perfect the kinds of steel already known, the examination of new steels by thorough testings as to their utility for the Krupp works, the undertaking of comprehensive researches into the properties and qualities of steel, and the attempt to make improvements in the field of steel production by free and independent experiments." F. A. Krupp converted his father to his own ideas on this subject, the old man gave his approval with the advice, that in making this innovation, the old principle should not be forgotten, of beginning in a small way and going on gradually to greater things. The oldest part of the factory adjoining the little family house was fitted up as the new laboratory. The need of testing the physical as well as the chemical properties of steel more exactly, soon caused an enlargement of the laboratory, and in 1895 it was transferred to large new rooms. Since 1898, it has been called the Institute for Chemical and Physical Research, and has been a valuable help to the shops in the further development of steel manufacture, especially of nickel steel and the modern special steels. Krupp always kept up a warm interest in the studies made in this Institute, and liked to have a report of them as often as possible. To the study of the purity, composition and of the properties of steel was soon added problems of a special nature. Experiments were made in measuring high temperatures in the furnaces, and in introducing practical means to this end; then experiments were worked out in the co-efficients of expansion of the different kinds of steel which were very important in the manufacture of guns; the electric and magnetic properties of steel were investigated, important for the production of the so-called dynamo steel, and numerous other problems of a scientific nature were attacked. As early as 1883 the Institute employed the microscope in examining the polished sections of steel. The work of this department increased so greatly that the rooms allotted to the Chemical-Physical Institute became too small, and in 1907 the erection of the above mentioned new building was undertaken; it was taken into use in 1909, and now contains the chemical laboratory for the shops, and the Chemical-Physical Institute.

Among the many steps forward which were made at this time in the foundries with the aid of the laboratories, we must not forget to mention a work in which F. A. Krupp took a lively interest. It was in a field where the English steel industry had long maintained its superiority to the German by employing very pure Swedish material, as well as by long practice; and until the 'eighties English tool steels were indispensable for the working of many articles of production, even in the Krupp factory. Now very important improvements were made in the manufacture of tool steel, partly by the adoption of better materials than puddled steel for the crucibles, partly by the above mentioned improvements in the production of dense castings. Not only was Alfred Krupp's wish, to see the last bit of English tool steel driven from his works, fulfilled during his own life, but the firm also succeeded in meeting English industry in the market with equally good, and even superior tool steel and tools. At the end of the 'eighties the result of these experiments was the production of silicon steel, which long maintained its ascendancy as a tool steel extremely suitable for the most diverse purposes; it has only been partially ousted from its position by modern rapid tool steel.— Another field in which F. A. Krupp was also deeply interested in the experiments and progress made in the different shops, was the improvement of steel by adapting the heat to which it was brought while undergoing the hardening and so-called quenching processes, to its composition and to the objects to be produced. Quenching means a refining of the texture of the steel by a special thermic process, simultaneously raising its tenacity and limit of elasticity. Long years before, Alfred Krupp had acquired great experience in this field, while manufacturing his rolls and dies. But the process was only worked out systematically in the 'seventies and 'eighties, and its adoption considerably extended. Among other improvements owing to these studies, those made in the manufacture of gun tubes and armour plates, are very noteworthy.

A strong current of new life was imparted to the Cast Steel Works under F. A. Krupp's personal lead by these and similar successes in scientific metallurgy. But in his practical measures too, in the extensions of the factory, and the establishment of new branches. Krupp showed no less foresight and decision than his father had done. On the contrary, encouraged by what had been achieved, and impelled onward by the rise of the international market towards the end of the 'eighties, he inaugurated, soon after his father's death, a new period of momentous alterations and enlargements in the Cast Steel Works which by the year 1893 raised the area of the buildings from 42 hectares to 51, and the number of those employed at Essen from 13,000 to 17,500. These building operations started with a complete alteration of the crucible-steel foundry, which, with its furnaces for 12 to 18 crucibles, and its other appliances, built in the 'seventies, could no longer keep pace with the existing demand. The object of the re-building, for which Mr. Asthöwer, among others, gave his counsel and aid, was in the first place to simplify the melting work, by combining the crucibles in larger furnaces. The modern improvements in building big steel-melting furnaces, especially those of Siemens, with freely developing flames, were of use here. An experimental plant of larger gas melting furnaces for the crucible process, had, in fact, been resolved on with Alfred Krupp's approval, and directly after his death the execution of the project was commenced. The foundry at the north side of the factory had been built at the very beginning of the works, and often added to since; at the time we speak of it comprised six bays, with a total of 136 furnaces. These were now altered into 17 big gas furnace, placed at regular intervals throughout the big centre bay of the foundry; each furnace was for 104 crucibles, from which ingots to the weight of 80 tons could be produced. A gas producer plant was erected for each furnace; the crucibles were heated in 26 furnaces of enormous size. The alteration proved most advantageous, and have remained unchanged in all essentials until the present time. The crushing and mixing of the crucible materials was rendered easier and cheaper by the employment of machinery.

With this re-building of the foundry, which really exceeded the needs of the moment, sufficient had been done for the requirements of crucible-steel ingots for a long time. The openhearth shop, however, had long been taxed to the utmost limits of its producing power. It had, as we have said before, been obliged to take over the entire work which had previously been done in the foundry "south side" with crucible furnaces, and it was used besides for many fresh experiments, among which those for the production of non phosphoric mild ingot steel have been described before. In the meantime, the basic open-hearth process had made great progress, and the recognised superiority of basic ingot-iron over acid iron, made it all the more expedient to introduce the manufacture of this product in greater quantities, as the former attempts to work up phosphoric iron in acid open-hearth furnaces had led to no lasting use of it. So in 1887 the crucible-steel foundry shop on the south side, which for some time had been of little use, was altered into a second open-hearth shop, which started work with two basic furnaces in the summer of 1888. By degrees this shop was enlarged to 7 furnaces, each with a capacity of 15 tons. Soon after a third and smaller open-hearth shop arose, in a part of the north foundry left free by the alterations of the crucible furnaces; this third plant began with one furnace, for the manufacture of mild castings from basic steel, and was gradually enlarged to three furnaces. Open-hearth shop III soon displayed an extraordinarily varied activity, not only in its own particular work, but also in the production of new kinds of steel with distinctive properties. After 1893 it produced considerable quantities of peculiarly pure steel high in carbon, such as had hitherto been the exclusive product of Swedish industry from its first-rate raw materials, and which was in use for scythes, files, hauling cables and other articles exposed to high strains. The production of this steel was afterwards transferred to the bigger open-hearth shop II, which had previously been chiefly engaged in producing mild steel for ship and boiler plates, for railway rolling stock, springs, axles, &c., as well as for the plate-rolling mill. The first open-hearth steel of extreme purity, as a substitute for puddled steel in crucibles, as well as numerous specialities in steel for other purposes proceeded from these two open-hearth shops. Their furnaces were considerably bigger than those of the oldest open-hearth shop, but the growing demand for steel soon necessitated still further enlargements. In 1891 a fourth open-hearth shop was set going in connexion with the armour-plate rolling mill, which had been erected in the meantime, this fourth shop had chiefly to supply the big castings for compound armour plates; mild steel slabs for big ship- and boiler plates, lastly heavy castings for ship- and machine building, *i. e.*, stem and stern posts, press cylinders, &c. It, also, has been considerably enlarged since its erection; at present it contains two furnaces of 40 tons each, and three of 30 tons each. Enormous ingots—among others that for the armour plate weighing 130 tons exhibited at Düsseldorf in 1902,—have been turned out of this shop. To answer the demands of such work, open-hearth shop IV has been equipped with four travelling cranes, each of 75 tons hauling power. The last and fifth open-hearth shop was built during F. A. Krupp's lifetime in 1900, to provide a big foundry with all modern appliances to meet the increased orders for open-hearth steel which were flowing in from other rolling mills. This last shop was first built with five furnaces each of the then notable capacity of 30 tons; this greatly contributed to cheapen the production of steel. In the equipment of the furnaces, too, and of the other plant this new shop differed from the older open-hearth shops. The charging platform of the furnaces was placed so far above the floor of the foundry, that the regenerators and valves under the furnaces, which in the old shops were at some considerable deapth under the floor of the foundry, were more accessible and therefore could be more easily repaired. Certainly the whole charge had now to be brought to the level of the platform by electric lifts. Here for the first time electric cranes were used in place of the clumsy steam or transmission cranes to handle the casting ladles, moulds and ingots; the furnaces were charged by machines driven by electricity of the American kind, so as to save time and labour, as just then wages were rising rapidly. Later on, when many rolling mills, and tube works, especially the Mannesmann tube works, ordered great quantities of steel billets from Fried. Krupp, the open-hearth shop V was enlarged to ten furnaces. With its up-to-date appliances it remained for many years the principal open-hearth shop at the Cast Steel Works.

This continued enlargement of the plant for producing steel could not but entail a corresponding increase of shops for working it. Though a constantly growing amount of steel and ingot iron was sent by the Cast Steel Works to other consumers, still the quantity of finished articles manufactured both for war and peace increased rapidly. The making of ordnance, especially the construction of big gun tubes and gun mounts advanced with giant strides to keep up with the rapid building of the German Fleet, in this way ever-rising demands were made in the working of heavy industrial products. The building of the gigantic new express steamers with their big engines, their colossal shafts and propellers set tasks which could not be executed much longer with the existing mechanical resources.

Most of the older mechanical workshops had, since the 'sixties, been taken over partially for the production of war material. Only mechanical workshop I was, after having been used temporarily for the manufacture of the first guns in the 'fifties, exclusively reserved for the making of peace material; it was helped out at need by the other mechanical workshops, and the turning shop for mounted wheels. But with the multiplication of the branches of manufacture and of the machine tools, the number of which rose from 700 in 1887 to more than 1000 in 1899, the space afforded by the old workshops was of course too small. An enlargement, and partial renewal by modernising the older engines and machine tools during the 'eighties, and another considerable extension of the building of mechanical workshop I in 1890, brought temporary relief only. These enlargements were soon insufficient to meet the rapid increase of the manufacture of steel products for building locomotive and marine engines, for stationary engines, for railway rolling stock, and many other purposes; and once again, shops intended for making war material had to be called on for help. During the 'nineties several new mechanical workshops were built rapidly one after another, but these had to be taken for working at war material, especially gun mounts and carriages, so that a large shop with up-to-date appliances was still lacking, which could be used exclusively and continuously for the manufacture of industrial products, such as crank shafts, and marine shaftings of which the weight was constantly increasing. In 1890/91, the want was at last supplied by the erection of mechanical workshop VIII. This stately building was placed immediately behind Alfred Krupp's monument at the factory gates, and with its imposing front and big windows-forms a great contrast to the older buildings. It is the most striking example of workshop architecture in the Cast Steel Works in this transition period, when the modern demand made by work for light, air and space had fully asserted themselves. Mechanical workshop VIII is an iron construction with outer walls of stone; 104 meters long, and about 22 meters high. It is divided into three bays with several stories in the side bays; it covers a workshop area of 9000 square meters. It is equipped with the most modern machine tools of every size required, so that the most complicated as well as the heaviest pieces used in machine building can be worked there. In the big middle bay of the shop stands among other tools, the giant drilling machine on which the trepanned marine shaft, measuring 45 meters in length, exhibited at Düsseldorf, was worked. The powerful crank- and thrust shafts of the biggest modern steamships can be turned and bored there, on machine tools of the heaviest build; for instance, a lathe for this purpose was erected in 1900, weighing

300 tons, its height of centres is 1800 millimeters, its useful length 24 meters. Almost simultaneously with the completion of this shop, modern rapid turning tools were introduced, they first came from America, and after the International Exhibition at Paris in 1900, they quickly made their way in the old world. These tool steels, in consequence of their composition, can stand a far greater heating, and therefore allow of far greater cutting speed than the older kinds; they were soon taken up by Krupp and brought to perfection, so that the great demand of the Cast Steel Works itself in this field was supplied by its own production. The employment of these rapid steels has given a new impetus to the German machine-tool making industry, which had already been favourably influenced by the introduction of American special machines. Both the construction and the driving of all machinery, have undergone radical changes under the influence of rapid steels with their high resistance and generation of heat. The substitution of gearing and electromotors, in groups or singly, for the old driving belts has completely altered the working and the appearance of the modern workshop, by abolishing all the transmissions. Mechanical workshop VIII was fitted at once for driving all the machinery by three-phase alternating current, and the cranes, too, the largest of which have a hauling capacity of 40 tons, are driven by electricity. This new shop now took over, in conjunction with mechanical shop I, the whole manufacture of peace-material, except a few productions en masse, such as sets of wheels, materials for the permanent way of railroads, and such like, which are made each in a special shop. A special shop had been started on the south side in 1871, for products for the permanent way, frogs, points, crossings, &c., and had been enlarged according to requirements in 1884 and 1890, but after mechanical shop VIII was ready, the other mechanical shops were used exclusively for gun building and the making of other war material. When the old mechanical shop I, soon after, had to make way for the new offices, a stately new building was erected in its stead in 1906 on the site of the former building yard; it took over the work of the old mechanical shop I and was started in 1907. This shop is also equipped with the newest and most suitable machine tools for speed and precision. Mechanical workshops I and VIII have an average total of 700 to 800 workmen, and besides the orders which come in from outside they are occupied regularly with important work for use in the factory itself; for Alfred Krupp's principle of building a great part of his own machinery is still followed. The number of machine tools employed in peace material in these two, and in the turning shop for mounted wheels, the large repairing shops and the shops for permanent way material amounted to 1900 in 1909.

The extension of the shops used for working war material, as we have hinted, was far greater than that of those used for peace production. As early as the first half of the 'eighties these shops, owing to the increasing size of guns, were enlarged and provided with more efficient machinery. An order for four 40-cm coast defence guns from Italy in 1882, especially occasioned considerable changes, such as the installation of big 60-ton cranes in several shops, of new lathes, drilling machines and other special machines for gun tubes up to 45 centimeter caliber, and over 15 meters long. So after Alfred Krupp's death, the building of new shops was continued still more rapidly. Gun shops V, VI and VII, two large mechanical shops for gun-carriage building and similar work, two boring shops, two projectile-turning shops, and other workshops for the fabrication of guns, projectiles, and fuzes, &c., rose up quickly. A great drawback had already made itself felt in the distance which divided shops working at the same products. Now, as these new buildings and enlargements were carried out, care was taken to assemble the shops which worked at the same branch, so far as the space available for building allowed; and the firm did not hesitate to undertake a considerable amount of rebuilding for this purpose. Thus in 1888, the iron foundry, which till then had stood beside mechanical workshop I in the old centre of the factory, was, to make room for the extension of the gun shops, removed to the south side, and placed beside the projectile foundry erected in 1880. The combined iron and projectile foundries on their new site, which is also in the vicinity of the various projectile turning shops, cover an area of 5600 square meters and employ on an average 500 men. In many cases, however, the scattered positions of the shops could not be remedied, and that was not only a palpable difficulty for supervision and sometimes a hindrance in work, but, what was more important, the transport to and fro of raw materials and half-finished articles it entailed, caused loss of time and increase of cost. It was left for recent times, by building and rebuilding, to remedy these evils, and to place the Cast Steel Works on a really modern footing also as regards economy of labour.

Among the shops which greatly gained in importance during the 'eighties and 'nineties, we must not omit the plate-rolling mill and the boiler forge with the shops belonging to them. The plate-rolling mill was started in 1879 to supply boiler- and ship plates for the Navy, and this branch of production grew so rapidly that up to the present time, Krupp has rolled more than 84,000 tons of ship- and boiler plates for the Navy. In 1883, the first large order of finished ships boilers was executed; it consisted of ten big boilers for Rio de Janeiro. As these boilers were too large to be transported by rail, they had to be carted to Ruhrort, and there shipped. In 1888, the construction of the first mild open-hearth ingot steel boilers was undertaken at the Cast Steel Works, they were intended for boilershop X, and introduced a new departure in boiler making; in 1891 the fourhundredth steam boiler was finished in the boiler forge of the Cast Steel Works, and in 1912, as far as can be foreseen, the thousandth will be finished. In 1892, the use of welded iron plates was entirely given up in boiler making, ingot iron had already taken its place in ship-building in 1885. Iron constructions of increasing number and size were gradually added to the previous work of the boiler forge, especially for the Cast Steel Works own new buildings. The enlargement of the gas works, the erection and frequent enlargements of the armour-plate rolling mill, the pressing plant, the iron buildings for the big open-hearth shop; for the mechanical and gun shops; and finally the buildings at the Germania-werft, the Rheinhausen blast furnaces, and the Krupp collieries, kept this shop long and seriously at work. But it has been qualified to meet these demands by the corresponding extensions that have been made, and by the adoption of modern appliances for the pressing process, hydraulic riveting, and still more recently by the introduction of the autogenous cutting and welding process, and of the acetylene welding process. In 1909, the production of the boiler forge amounted to 16,000 tons, of which 11,000 tons were iron structures, boiler- and other plate work.

Noteworthy improvements have been introduced by the increase in technical resources. We have already mentioned the improved machine tools. By the introduction of forging presses for the heaviest pieces instead of steam hammers, by the adoption of electric cranes and means of handling in the shops, both time and labour were saved. Forging presses were first used at the end of 1890, when a big hydraulic press of 2000 tons pressure was set up; a second of 5000 tons power followed in 1892. So began the gradual disuse of heavy steam hammers and the substitution of forging presses at the Cast Steel Works. Whereas the older presses had been chiefly used for shaping half-finished or finished pieces, such as parts of gun carriages, the big new forging presses now took the heaviest crucible and open-hearth ingots, for big guns, shaftings and crank shafts, as it has been found that the slow and penetrating pressure of the presses is more adapted to the thorough working of heavy masses. The first big presses were worked on purely hydraulic principles, whereas a system of combined steam and hydraulics is employed for the newer ones. The first forging presses, to which others for bending and shaping the plates were soon added, were put up in a large pressing plant connected with the armour-rolling mill. The heavy forged pieces were conveyed to the presses and placed under them by three cranes of 75 tons hauling power each, and one of 150 tons. The demands on the hauling and handling appliances in the factory rose altogether in the 'nineties, with the increasing number and size of the ingots to be worked. The call for them grew constantly in the foundry and the forges, in the rolling mills and the workshops; it was really fortunate that just at this time, a radical change and improvement took place by the introduction of electrically worked hauling appliances, and considerable improvement in the means of transport. The first electric crane in the Cast Steel Works, with a hauling power of 75 tons, was built in the shops of the factory in 1893; its electric equipment, that of a so-called triple motor crane, came from the Siemens works. The hauling appliances set up in the following years were constructed as single motor cranes, till the system was given up later in favour of the employment of several motors. By degrees the majority of the older cranes were also altered for electric motive power. The importance of this innovation can best be judged from the fact that a crane driven by electricity can travel 150 to 200 meters in a minute, while the transmission cranes formerly used had a speed of 10 to 15 meters.

The production and distribution of motive power had to keep pace with this development of the machines and means of transport. This was effected not only by multiplying and enlarging the existing steam engines, but also by adopting all the technical improvements which had been made in the meantime. The use of condensation must be spoken of here. The first steam engines with condensation by injection were those for the beam engine at the water works on the Ruhr, started in 1874; from 1880 a central condensing plant of modest extent was at work in the tyre-rolling mill; the neighbouring Sälzer pond was used to cool the injection water for this. Subsequently central condensation plants were erected for a number of large groups of engines, a system which has been abandoned from technical reasons in the new steam-turbine installations. The water is now cooled according to the latest improvements, in cooling towers. Further progress in the economical use of steam engines was attained by raising the pressure. As most of the boiler groups are connected by a circular main pipe, the pressure could only be raised slowly by cutting off the oldest boilers as required. The pressure was not brought up to 6 atmospheres till 1902, and it will soon be possible to raise it to 7½. For some new groups of steam engines with their own boiler plant, of course, a higher pressure is possible even now. For instance, in 1901, a number of big double boilers for 12 atmospheres for high pressure and steam super-heating were started, combined with a number of triple expansion engines from 1000 to 1200 horse powers. Steam turbines have been used since 1905; there are now about ten at work, with a total efficiency of 14,000 horse powers, most of these have been made in the works. The number of steam boilers, which in 1887 was 230 in 29 plants with a heating surface of 15,000 square meters, had risen by 1911 to 337 boilers in 28 plants, with 35,500 square meters of heating surface. The efficiency of the boiler groups has been considerably raised in recent times, while their number has been lessened. The great system of steam pipes in the Cast Steel Works is at present upwards of 60 kilometers long. The number of steam engines is 540, with a normal output of 71,000 horse powers. The consumption of steam by the triple expansion engines and steam turbines of now-a-days is about one third of that consumed by the older non condensing engines with expansion valve gear.

The employment of more powerful machines has been greatly favoured in recent times by the rapid spread of electric works. The production and appliance of heavy currents began in the Cast Steel Works almost simultaneously with the great inventions of Edison, Siemens, Schuckert and others, who in the 'seventies and 'eighties laid the foundations for the modern development of electric lighting and motive power. In mechanical shop I and the boiler forge, the first electric arc lamps were taken into use as early as 1876, and were at first fed in the manner then usual by a machine to every lamp. At the beginning of the 'eighties the first machines for several arc lamps connected in series were used for lighting the Bessemer shop. In 1882 the first experiments were made with incandescent electric light; they were so successful that in the following year, the reception rooms at the Hügel were supplied with such lamps, and in 1885 they were adopted in the Administrative Building of the Cast Steel Works. Henceforth electric lighting spread rapidly in the workshops and open spaces, and in 1888, an electric power station was built on the north side of the premises with two 100-horse power twin steam engines, which had been built in mechanical workshop I, to drive several dynamos for arc and incandescent lighting. In the meantime, after 1890, electricity was put to much more general use, especially as motive power. The driving of machine tools, cranes, &c. by electric motors took large proportions, and this quickly led to considerable extensions of the electric works and to the employment of more powerful machinery; by degrees five sets of compound engines each of 500 horse powers were erected for the production of a continuous current. This carried the electric station to the limits of its power about 1900, so that the erection of a second station was necessary. Here, too, only continuous current was at first produced. But in 1902, when an experiment was made in mechanical shop VIII to drive the machinery by three-phase alternating current, this was at first produced by a transformer in the workshop itself. In 1905 three-phase alternating current was produced by the first steam turbine in electric power station II; and it was soon carried into other shops, for instance, gun shop IX; and it was used for pumping at the colliery Sälzer &Neuack. The consumption increased so greatly by this, that the plant was enlarged to five turbine generators. At the same time the continuous current plant in the electric power station II could not supply the whole demand, so that it had to be supplemented by the erection of five turbine generators. In 1907 a third electric power station was built where high tension alternating current was produced for working the electro-steel plant. In 1910 there were 26 piston steam engines and 10 steam turbines active in the electric power stations of the Cast Steel Works, with a total output of 24,000 horse powers.—Of course the feeble current plays its part in the various branches of employment as well as the current of high tension. Soon after the introduction of the electric telegraph in the middle of the last century, the first telegraph wires, on the simple dial system, were laid between Alfred Krupp's office and his private residence. Then communications were established with the Cologne-Minden and Berg-Mark railways, and in 1867 between the Hügel and the factory, these last with dial apparatus. In 1870 the apparatus was replaced by the Morse system.—The adoption of a telephone service in the Cast Steel Works began in 1881, with a few connexions; this means of communication has developed extensively; there are now more than 600 call stations. There are besides 126 secondary stations for connexions with the State telephon service. From the end of 1911 the connexion of telephones in the internal service of the factory has been worked automatically.

The events and changes just described as taking place between 1887 and 1902, present a picture of brilliant and almost uninterrupted progress. Subsequent chapters will show what share the technical improvements in the production of war material, and the enlargement of the outlying works have had in this enormous growth of the works, and how its evolution is reflected in the extension of the institutions for social betterment. In order better to understand this growth which looks doubly brilliant beside the comparatively slow progress of the previous fifteen years, we must bear in mind that it took place at a time when the whole of German industry was making its most rapid advance, after a long spell of patient waiting, an advance which a few short reverses scarcely affected. The first years of F. A. Krupp's ownership of the factory were marked by a decided improvement of the industrial market, which after several years of depression began to affect the iron trade in 1887, coal mining in 1888. It was chiefly the big orders from the German State railways which had a favourable effect on the iron market, while foreign trade, on account of lower offers from England, had still to struggle against difficulties. There was, truly, a great depression in trade from 1892 to 1894, which paralysed foreign trade in particular, and made it seem quite purposeless to send German manufactures to the Chicago Exhibition. Here F. A. Krupp's sense of the duty he owed to his position stood him in good stead. He saw in the name of Krupp a programme which bound him to take part in such an important industrial competition. At his desire the firm strained every nerve to represent German industry worthily and largely, and when success surpassed expectation, Krupp could feel assured that by the expenses he had not shrunk from incurring, he had been a chief agent in obtaining it. The period of commercial depression was however of shorter duration than former ones; better times began again in 1895, and went on steadily improving from 1896 to 1899. The founding of a number of syndicates,—notably the coal syndicate in 1893, helped to making a temperate use of this revival of trade, and to the prevention of immoderate production and speculation, the fatal consequences of which had so often been seen in former reverses of trade. Indeed the great commercial prosperity which had called all the powers of industry into play, declined in 1900, and gave place to a considerable falling off in trade in 1901/02. But in consequence of the moderation which had prevailed during the great prosperity, the depression was not accompanied by the disastrous consequences which had always marked such periods hitherto, indeed it soon gave place to a general improvement. Very large orders from the American market, the importation from which was at that time still greater than at present, helped the Cast Steel Works through the crisis at home, and the brilliant Düsseldorf Exhibition of 1902 marks the opening of a new, vigorous, upward movement, in both home and foreign trade which has continued uninterrupted until the present.

A development like this, which brought an unexpectedly great increase of every branch of production in the Cast Steel Works, of course doubled the duty of securing the foundations of the great enterprise, and of devoting more attention than ever to its financial basis. We have already, in the story of F. A. Krupp's life, alluded to the way this principle was carried out in the financial management. But the technical economy of the factory, the supplies of ore and coal and the manufacture of pig iron, had to keep up with the growing demands of the times. As far as obtaining ore went, Alfred Krupp believed he had secured his enterprise for a long time to come, but no one could then foresee what dimensions the production of pig iron and steel would assume in the twenty years that followed his death. Since the 'seventies the Orconera mines had been the most important source of ore; at the same time small quantities of spathic ore, hematite, and manganiferous ores from the Lahn and Sieg district had been smelted. The demand of the factory was well supplied from these sources of its own, even between 1870 and 1880 when the firm's production of pig iron increased tenfold; and they remained sufficient until Alfred Krupp's death, as in the first half of the 'eighties there was only a fluctuating and on the whole unimportant rise in the production of pig iron. Towards the end of the 'eighties however, when another increase in the demand for iron began, considerable quantities of foreign ore had to be bought, as had been the case before the acquisition of Orconera, and still more in the 'nineties, when the smelting of non manganiferous hematite was taken up, in addition to the former production of manganiferous Bessemer pig, hematite, steel and Spiegel iron. Further supplies again were called for when the iron works at Rheinhausen were started in 1897, as Krupp's own ores were neither sufficient in quantity nor suitable in quality for these blast furnaces. Ore was procured in considerable quantities first from Elba, then from Spain, Turkey, Africa and the Caucasus, even from India, Brazil and Japan. Thus the iron-stone stores at the Krupp works presented the greatest variety at that time. The firm, however, had already bought the concessions of "Langenberg" and "Luxemburger Grenze" in the oolitic iron-ore district in Lorraine, as they were considering the possibility of soon introducing the Thomas process, and in 1894 this Lorraine property was enlarged by the purchase of the Ida and Amalie mines near Aumetz. The execution of the plan for a big Thomas plant was postponed for sometime, on which account the ore from the Lorraine mines was not used for supplying the Cast Steel Works at once. They were only opened up in 1900, by building extensive pit plant, and when the Thomas process was started in 1905 at the enlarged Friedrich-Alfred-Hütte, a new era in the manufacture of Krupp pig iron was inaugurated.

As to the coal supply, the collieries which Alfred Krupp had bought were a sure provision for the next twenty or thirty years. But the rapid increase in the production of pig iron towards the end of the 'eighties raised the demand for coal so greatly that the firm could not supply more than half from its own mines. The purchase of the colliery Sälzer & Neuack, the shares of which had been nearly bought up by Krupp in 1889, was to some extent a help. But the further development of the factory which proceeded especially after 1894, in the most unforeseen manner, and the necessity of keeping the works as independent as they had now become, even of the coal syndicate founded in 1893, made it advisable for the firm to take further steps for securing a provision of coals of their own. The colliery Hannibal, near Bochum, which touches the coald field of Hannover, was bought in 1899, the efficiency and output of this pit was soon raised by putting up new hauling plant and making great alterations. In 1901, Sälzer & Neuack became the exclusive property of the firm. In F. A. Krupp's lifetime a number of coal fields on the Dortmund Ems Canal were bought in combine with the North-German Lloyd and formed into a mining company, the Emscher Lippe Co. The building of a double pit plant was at once begun, and in 1906, the first coals were raised, which by 1911, increased to an annual output of 800,000 tons. Thus the factory's coal supply from its own mines could be brought up again to the amount required for consumption which had been considerably in excess since 1905. The total output of the collieries belonging to the firm, including the half-output of Emscher Lippe, amounted in 1910/11 to over 2,900,000 tons. The enormous rise in the demand for coke, which was particularly noticeable after the opening of the Friedrich-Alfred-Hütte, and has more than doubled during the last ten years, necessitated a proportionate extension of the coking plant. A plant of 60 ovens was built at the Hannover pits in 1895, another of similer size at Sälzer & Neuack in 1901, a third at Hannibal in 1904; several considerable additions have since been made to the coke-oven plant, which at present take more than half the coals used in the Krupp works. The total consumption of the Cast Steel Works with all the outlying works amounted in 1910/11 to a round sum of 3,000,000 tons. About half of that, in the form of coke, goes to the Friedrich-Alfred-Hütte.

Now we must return to the development of the Krupp smelting works since 1887. The insufficiency which had already made itself felt, became troublesome when the call for pig iron in the Cast Steel Works rose rapidly after 1887. By modernizing the blast furnaces, their efficiency was adjusted as nearly as possible to the rise in the demand. Between 1890 and 1895 the furnaces on the middle Rhine were improved by the putting up of Cowper hot-blast apparatus, a measure which not only increased the output considerably, but also lessened its cost. But radical improvements and enlargements could not be made, owing to limited space, especially in the Johanneshütte, so that the building of new iron works was more urgently necessary than ever.

The plan which had been formed with Alfred Krupp's co-operation, of uniting the Bessemer steel shop with the smelting furnaces at the Johanneshütte and of transferring the rail manufacture thither was, as we said before, not carried into effect. The first doubts as to the suitability of this solution of the difficulty were aroused by the unexpectedly rapid spread of the Thomas process. The Thomas-Gilchrist invention of the basic converter process had really met with the warmest recognition and made the greatest progress in Germany. As early as 1879 the Hörder Company and the Rhenish Steel Works had combined in the purchase of the patent for the whole of Germany, and the Thomas process had been introduced at these two works. Other iron works in the Rheno-Westphalian district; for instance Bochum, Oberhausen, and Phönix soon followed suit, and in 1883 Germany possessed more Thomas works than any other iron-producing country. In the following year the production of steel by the basic Thomas process and by the acid Bessemer process was about equal, but in 1887, a million tons of Thomas steel were produced as against 430,000 tons of Bessemer steel. So a change over to this new process, which had proved so eminently suitable for German ores, was for the Cast Steel Works too, only a question of time, and under these circumstances the rebuilding of the Johanneshütte with its antiquated appliances and limited space seemed less advisable than ever. It had also to be well considered if an enlargement of any of the Krupp furnaces on the Middle Rhine were worth while; now that the Lorraine industry had developed so enormously by the inexhaustible supplies of phosphoric ores which the Thomas process had shown the value of. The first result of these deliberations was a postponement of the measures proposed. Then in 1889 the already mentioned purchase of the "Minette" mines in Lorraine was begun, so that in any case the demand for phosphoric ores for the Thomas process could be supplied for the present.

Meanwhile the increased cost of pig-iron production made it more and more apparent that the plant of the Krupp blast furnaces had gradually become antiquated; this pointed forcibly to the necessity of either modernizing them or of erecting quite new plant, if the Cast Steel Works was not to get into difficulties with its large demand for pig iron. As to the works on the Middle Rhine, not only their situation, but their distance from Essen rendered them unsuitable even after the improvements we have mentioned had been made. Again, the Johanneshütte, which was nearer and in a better situation, worked under difficulties as compared to modern iron works on account of its small furnaces and old fashioned appliances. Besides it could only pretend to supply a small part of the Cast Steel Works demand for pig iron. It was clear that neither the situation, nor the extent of building land available would suffice to make them really modern iron works fit for later extensions. It was even less possible, considering the rapid development of the iron industry at the beginning of the 'nineties, to think of building modern steel works and rolling mills there as well as blast furnaces. So fresh plans were weighed. The old idea of building blast furnaces at Essen in the immediate vicinity of the Cast Steel Works revived once more, but again it had to yield to much the same objections as before. It would also have been unadvisable to build large modern iron works on ground so much honeycombed by mining as that near Essen is. Krupp smelting works in Lorraine were also suggested, but again the distance from Essen and the perilous proximity of the French frontier in case of war prevented the adoption of the plan. All discussions only ended by pointing to the same solution: namely the necessity of establishing large iron works on the Lower Rhine in the immediate vicinity of Essen. This solution was, moreover, favourable for the import of Spanish ores with which the firm was provided for many years to come. At last in 1895, the firm succeeded in purchasing property of considerable extent at Rheinhausen on the left bank of the Rhine, and thus settling the knotty question of the site of the new iron works; the building of which was awaited with impatience by all concerned, especially F. A. Krupp, who correctly estimated the importance which the enterprise would have for the firm in the future.

Plans for carrying out the building on a large scale had already been made. There were to be five blast furnaces of the largest kind, a Thomas steel-making shop with three converters and a rolling mill for rails, sleepers and billets. Expedition in the completion of the blast furnaces was a most urgent matter, so that the burning question might be solved of an adequate supply of cheap pig iron for the Cast Steel Works. The building of the steel plant, for which certainly no other but the Thomas process would be adopted, was a secondary consideration. The building of the blast furnaces was begun in 1896, the two first were started at the end of 1897, and the third in 1898. They were each of 400 cubic meters capacity, the daily output 200 tons. The production was at first restricted to Bessemer and hematite pig iron, for the requirements of the Cast Steel Works.

While the furnaces were building a port was laid out in front of them parallel to the Rhine; it was 60 meters broad and the wharf was 300 meters long, fitted with four electric handling cranes. Between the port and the furnaces is the yard for the storage of ore; this yard is spanned over by the unloading cranes; immediately in front of the furnaces, iron store tanks are erected from which the ore can be dropped into the ore wagons, as they pass below. The ore supplies from the sea are towed up the Rhine, from the mines of Central Germany they are transported by railway; the ore, fluxes and coke are then raised to the mouth of the furnaces by perpendicular lifts. The gas from the furnaces heats a battery of 30 steam boilers which were made in the boiler forge at the Cast Steel Works, the boilers supply steam to the blowing engines, the engines in the electric station and the water works. After these thoroughly modern blast furnaces had been started, the Cast Steel Works' entire demand for pig iron could be supplied from this source, and it was possible to restrict the working of the older furnaces which were inadequate either on account of their situation or of their plant; they could now be kept for the production of special sorts of pig iron for sale. In 1904 the Johanneshütte was stopped after working for 32 years under Krupp management.

When the new iron works were completed, part of the problems were solved which had been claiming consideration for a long time. The laying out of modern steel works, with rolling mills connected had been deferred to more urgent work, chiefly by the purchase and enlargement of the Germaniawerft. But soon the already mentioned defects in the Bessemer shop and the rail production at Essen became more and more noticeable. F. A. Krupp himself devoted much interest to the question. In 1899, when the new iron works at Rheinhausen had hardly got into full working order, he insisted on the pressing need for an extension of the buildings to the size at first resolved on. While at his desire, the plans were being revised and enlarged to meet the ever-growing demands of the German iron industry, it was possible to make another considerable purchase of land at Rheinhausen, so that 1000 "morgen" could be put at the disposal of the new buildings. In 1900 an open-hearth steel shop with two furnaces of 25 tons capacity each was built for the first experiments in working up liquid pig iron immediately. The entire plant and premises of the iron and steel works was designed by the new plans for a present output of 500,000 tons of pig iron. In spring 1902 the general plan for the new buildings was finally approved at a meeting held at Hügel with F. A. Krupp as chairman. In October, after thorough revision of the plans, credit was granted by the Directorium for the first part of the great work, the extension of the blast furnace plant. Krupp's assent to the resolution was his last important action in the furtherance of the Cast Steel Works; he added to his assent the hope that the building of the steel works would proceed as quickly as possible. He himself saw neither the execution of the one or the other, he who had given his unabated interest to these plans for many years was not to see the works at Rheinhausen in their perfection. Still the general plan of the whole could be submitted to him, and on January 23rd, 1903, Frau Krupp gave her assent to the sum allotted to the building of the steel works. The erection of new blast furnaces was immediately begun, and in June 1904 the first of them, with a much larger output than the old ones could be started. As the same time the former name, "Rheinhausen Ironworks", was changed to "Friedrich-Alfred-Hütte", so that this great and promising enterprise might be associated for all time with the memory of its founder.

## THE CAST=STEEL GUN SINCE 1887.

Artillery has had its prominent share in the progress that technical matters underwent during the last twenty years, owing to the application of scientific methods. A comparison between a modern recoiling gun and the guns in use during the 'seventies and 'eighties will be sufficient proof of this statement. The period after 1887 is mainly characterised by the development of the quick-fire system, which has continued down to the present day. The first beginning of this movement dates much further back, as has already been shown; the same as the first fundamental progress obtained by the design of a quick-fire breech mechanism and the use of metal cartridge cases. The brass cartridge case could dispense with any obturating device at the front face of the breech mechanism, so that the obturator ring could be suppressed, which constituted a weak point of the breech-loading system, and besides was a nuisance for the servants. Besides, there was no need any longer now of a vent, which again was in favour of raising the firing speed. Even the first steps aiming at checking the recoil and at the automatic return to battery of the gun, why even the use of a powder developing little smoke are things that go back to an earlier period. All that has been mentioned formed a basis on which the Krupp works now could continue to evolve the system of the quick-fire gun. The leading idea laid down from the beginning that quick fire was not of itself the object to be pursued, but that the road to be followed ought to lead to simplifying and facilitating the attendance of the gun by improvements in design of all parts of the gun, was unswervingly adhered to down to the present day. Quick-fire arrangements therefore could not be restricted to certain species of guns, but had to be extended to all alike. The task set therefore was to develop and apply the system of checked recoil and automatic return to the firing position, which was first obtained in naval and coast-defence guns, also to gun carriages on wheels, viz to siege and fortress, field and mountain ordnance. It was for the gun designers and builders to work out the fundamental ideas, and to find the means and ways of letting all the guns partake of the improvements, without, however, impairing the scope of their tactical application. The rise of ballistic power and efficiency of each particular kind of gun was an attendant moment: for the guns fighting against armour, they meant increase of the penetrating power of their projectiles; for the field guns, a flatter trajectory; for the naval and coast-defence guns, greater ranges in proportion as the fighting distances augmented; the same applied to siege artillery; finally, curved-fire guns had to develop so as to be able to respond to the varied and manifold tasks that are set them; but also gun tubes, breech mechanism, the long series of different kinds of mounts and carriages, the laying gear, the projectile and fuze had to undergo improvements in order to come up to the level of what was demanded of them. Thus it came about that artillery during the many centuries of its existence did not experience such revolutionising improvements as within the short space of the last quarter of a century.

Speaking first of the gun tubes, it was again the improvements that powder had undergone, which mainly called forth essential improvements of these also. It goes without saying that the use of explosives, which had been the result of researches aiming at gun powders possessed of higher propelling power and producing less smoke, suggested experiments with a view to utilize them as explosive charges for shells. As early as the beginning of the 'eighties, wet gun cotton had proved to be serviceable under certain conditions as an explosive charge for long shell fired from mortars. In 1885, picric acid had been used in France under the name of melinite as bursting charge for shell fired with high muzzle velocities. In Germany, it was after that also introduced as explosive charge for field-gun shells. This innovation, however, brought on, so it seemed, a serious crisis for cast steel as a gun metal, for it was found that shells filled with picric acid accidentally exploding in the bore, also caused the cast-steel field guns C/73 to burst. Trials were consequently made which led artillery experts to believe, that bronze guns in such accidents were less perilous to the men, and that this metal therefore ought to be preferred to cast steel. From the experiments with nickel-steel alloys, the Krupp works, however, had in the meantime already found out the superiority of that compound as regards tenacity and resistance when compared with ordinary carbon steel, and in November 1889 therefore they went in for trials with a view to examine the resisting power of nickel-steel gun tubes against shells bursting in their bore. These trials were attended with full success, and in June 1890 the first 9-cm field gun C/73 was manufactured out of the new metal, which was absolutely proof against the effects of a shell filled with picric acid bursting in the bore, and which was adopted by the German field artillery under the denomination C/73/91. As nickel steel had a tendency to enclose many gas bubbles of varying size and distributed unequally throughout the fluid mass, which considerably impaired its fitsness as a gun metal, long and wearisome experiments were necessary before a close and uniform texture could be ensured. The Krupp works not only mastered fully the difficulties alluded to, but also went on improving nickel steel considerably, and eventually to give it a resistance and so high an elastic limit, as rendered it superior to any other kinds of steel hitherto ever used for making guns. All component parts of gun tubes are now manufactured by the Krupp works from this special nickel steel. The improvements as regards the quality of steel were attended by others bearing on the design and the mode of the building-up of gun tubes which by that have been carried to essentially higher efficiencies. A comparison between guns of the same caliber, dating one from older, the other from recent times will best elucidate this. The Prussian 9-cm cast-steel gun C/61 showed a muzzle energy of 36·3 meter tons, which means 84·3 meter kilogrammes for each kilogramme gunweight, the modern cannon nearest to it in caliber, the 8·8 cm naval gun L/50 has 420·5 meter tons muzzle energy, that is 11·6 times as much, the quotient of efficiency here is 306 meter kilogrammes to each kilogramme of weight of gun. The Prussian 15-cm cast-steel gun C/64, which came into action during the sieges in France, showed 131 meter tons muzzle energy, the 15-cm naval gun L/50 produces 2045 meter tons; the respective efficiency quotients are 52·3 meter kilogrammes for the former and 366 for the latter. Both the 9-cm gun C/61 and the 15-cm C/64 were massive guns, that is made of one solid piece, those compared to them are built-up on the jacket and jacket-and-hoop system respectively. As these by their very construction show a superior efficiency, it will be interesting to compare the progress made in this respect within the period when built-up guns came in. The 30·5-cm had an efficiency quotient of 89 meter kilogrammes in 1873, 131 in 1882, 172 in 1890, 303 in 1899, 327 in 1901 and 366 in 1906. In 1873 this gun weighed 36,600 kilogrammes and produced 3270 meter tons kinetic energy at the muzzle, the modern 30,5-cm gun L/50 weighs 47,800 kilogrammes and has 17,510 meter tons muzzle energy. The weights of the two guns therefore show a ratio of 1 : 1·3, their respective muzzle energies however 1 : 5·3.

The invention of smokeless powder was the fundament for the evolution of artillery towards quick fire guns, their very existence derives from it. In the times of the old powder, both friend and foe were wrapped up in impenetrable clouds of smoke after a few rounds, there was no chance for quick fire then. The attendânce of the gun besides was encumbered by the residue the powder left in the bore. On July 3rd 1889 Alfred Nobel had applied for a patent on the invention of nitroglycerine powder. It is probable that Alfred Krupp's well-known active interest in the promotion of powder questions caused Alfred Nobel to turn up personally at Essen 10 days after, on July 13th, bringing with him a small quantity of the new powder. That very same day trials were begun with this powder, which was of cubical form measuring 3·5 mm each side. It was fired from a 5-cm quick-firing gun on the proving ground of the works at Essen. The result was a surprise. The powder when fired only gave off very light clouds of vapour that quickly vanished, a charge of only one third the normal weight produced the same initial velocity as the old powder, yet much lower gas pressure. Krupp at once ordered a large quantity of the powder with cubes of various sizes up to 15 mm length of side, and in Octobre 1889 commenced a series of trials from guns of all calibers up to 30·5-cm, the latter gun having 35 calibers in length. The most favourable results of these trials led to the adoption of the powder under the denomination of W. P. C/89 (Würfelpulver) or "Smokeless Powder C/89". It could justly be styled smokeless, for except for an insignificant quantity of ashes it only gave off gas, what was visible in the air after the round was fired, were the vapours of water which became condensed as they left the bore, and nitrogen which formed nitric acid with the oxygen of the air. Smokeless powder has in the course of time undergone a series of modifications in order to suit it to its various objects. There are 20 kinds of it in use now at the Krupp works. The percentage of nitroglycerine, which at first was 50, has been lowered to 25 in order to the keep down the temperature of combustion and thereby to diminish the erosions in the bore. For the same reason in many cases pure gun-cotton powder is used, although its ballistic efficiency is inferior to that of nitroglycerine powder. Tubular powder came into use in 1893, which resembles in shape to macaroni. According to the size of the powder charge, and the caliber for which it is used, the inner and outer diameters of the tubes vary, they are cut to lengths to suit the cartridge cases and are then bundled together. The tubular form is the most suitable, so far known, for smokeless powder as regards uniformity of ignition and combustion.

After smokeless powder had paved the way for the tactical use of quick fire, the technical improvement of artillery went on in huge strides at the Cast Steel Works. The first and foremost attention was turned to the breech mechanism, the progress and application of which to larger calibers largely depended on the advances made in the manufacture of cartridge cases. Since the commencements of this branch, of which mention was made in a previous chapter, the two German manufacturers Lorenz at Karlsruhe and Arthur Krupp at Berndorf, who had taken it up, had made large progress. As early as 1888, Krupp could fit a 13-cm gun with a "quick-fire breech mechanism", and in 1890, a 15-cm gun. In 1895 cartridge cases could be made for 24-cm caliber and in 1899, for 30·5-cm. The breech mechanism first used was the cylindro-prismatic quick fire wedge C/87 for which was substituted in 1895 the wedge with guiding screw shaft which down to these days has been the prevailing mechanism. This wedge breech mechanism was the outcome of many years' efforts to develop the transport screw, applied already to the cylindro-prismatic wedge C/66, into a single-action screw, that both moved and locked the wedge. For the old hammer lock the percussion lock with striker soon was substituted, which was operated by a single-action cocking and firing device in 1895, this again in 1900 was improved into a repeating or recocking device. Naval and coast-defence guns have firing arrangements now, permitting to be operated both by hand and electrically. The vertical block which was abondoned for bigger calibers in favour of the horizontal wedge with guide-screw shaft, was again applied afterwards to calibers up to 15 and 21 centimeters, in cases where want of space interfered with the lateral movement of the horizontal wedge, for instance for guns in armoured turrets of inland fortications. The weight of the vertical block for big calibers formed no longer any obstacle now since a spring had been inserted, which is compressed by it, when the breech is opened, and helps to lift it in the upward closing motion. The Krupp gun to fight air ships also is fitted with a vertical breech block, as it has to fire at very high elevations and this breech mechanism allows of inserting the cartridges from above, which means a considerable facilitation of loading. About the beginning of the 'nineties, a horizontal breech mechanism with crank lever, carried out in various modifications, was constructed, taking over some of the ideas suggested by the vertical block. This system had been resumed during the last ten years, it is now, after having been improved and simplified, that Krupp breech mechanism which is most frequently applied. All field and mountain guns, siege guns up to 15 centimeters caliber, as well as howitzers, even up to 28 centimeters caliber are now fitted with the horizontal breech mechanism, unless for special reasons a screw breech or an automatic mechanism is used. With all medium and big calibers of naval and coast-defence guns, Krupp uses both the single motion wedge with guiding screw shaft, and the horizontal mechanism with crank lever. The breech wedges of the biggest calibers can be operated both by hand and by hydraulic power, so for instance the breech-closing mechanism of the 35·5-cm gun L/50 which was built in 1911, is fitted with an hydraulically worked wedge with crank lever.

In 1902 Krupp was set the problem to give a greater firing speed to the guns intended to fight against torpedo boats. This implied a change of the breech mechanism, which in its form then did not allow of any increase in that respect. Such increase, it could not be doubted, was only possible for a breech mechanism that worked automatically, by utilising the energy of recoil for the opening and closing operations of the breech wedge. The 5·2-cm gun L/55 with automatic vertical breech block was built on such principles in 1902. During recoil the block opens automatically and again closes of itself, when the cartridge is inserted. For well aimed firing, 45 to 50 rounds a minute could be obtained with this gun. Since that time numerous vertical and horizontal breech wedges, operated by a crank lever, have been fitted with arrangements for the automatic opening and closing; they have been made for guns up to 15 centimeters caliber. Krupp did not, however, stop short at applying such breech mechanisms for naval and coast-defence guns only, but also utilised them for mountain, field and siege guns. The Netherlands were the first state to adopt a 7·5-cm Krupp field gun with automatic breech mechanism for their colonies in the year 1910. As an ulterior development of the idea which lies at the bottom of the automatic breech mechanism, a gun for the attack of torpedo boats of a more advanced system was built in 1906, its breech arrangements were amplified by the addition of devices for automatic firing and loading; the outcome was the first 8·8-cm self-loading gun. A cartridge magazine is fitted above the cradle and feeds automatically the breech, the projectile is automatically inserted and closes the mechanism, and when this is locked, the gun is automatically fired. The gun may be operated, however, also in this way, that single rounds may be fired by hand, also the automatic loading device may be shut off, so that rounds can be fired by single loading. Self-loading guns have been built up to the present with calibers ranging from 5·3 to 12 centimeters, the 7·5-cm automatic gun L/50 can fire about 40 rounds a minute, the 12-cm gun 25 rounds.

Although Krupp on principle favours the wedge breech mechanism, to which besides the works adhered ever since they made guns, they devoted themselves in 1891 to working out a screw breech mechanism with stepped screw, which after some further modifications was fitted with a crank lever, that permits opening and closing the breech in one single action. This breech screw may be fitted with plastic gas check or arranged for metal cartridge cases. An eccentric screw breech mechanism which cannot be swung out, has been manufactured on special demand, but as the breech requires to be considerably enlarged in diameter for this mechanism, it is useful only for guns of small caliber.

The quick-fire breech mechanism for quick loading only fulfilled one of the conditions upon which depended a simplification of the attendance of the gun, which again might lead to an increase of the firing speed. To make it complete the carriage also had to be provided with arrangements to lay the gun quickly. The way in which this was obtained for naval guns by the small upper carriage with automatic return to battery and which was checked during recoil by a brake, has already been described. It has also been mentioned that the use of a ball bearing considerably enhanced the facility of lateral training. The problem now was to apply the arrangements from stationary guns to carriages on wheels, as they were used for fortress, siege, field and mountain guns. The difficulties of the problem presented consisted in this that the recoil had to be so checked and the automatic return to battery so effected, that the gun remained unmoved in the firing position, and that a correction of the pointing could be dispensed with; at the same time, however, the transportability of the gun should not be affected. The first trial gun brought out about the middle of 1887, a 6-cm quick-fire gun L/40 in a garrison carriage on wheels, still has the characteristic arrangements of naval mounts. The gun could be traversed about a fixed pivot on the platform, the gun tube lay in a small upper carriage that recoiled on a chassis and ran out automatically to the firing position. To obtain the fine adjustment for lateral training the upper carriage could be traversed on the chassis. Hand wheels for the pointing arrangements, an armoured shield, even a seat for the pointer recalled the naval mounts. This gun, as well as a similar 5-cm quick fire gun L/40, were called forth by a desire prevailing at the time to beat off assaults on fortresses by a mass fire from small caliber guns. These trials with fortress guns, were of little use only to enlighten the question what arrangements were to be given to a quick firing field gun. For the stationary pivot which in this construction checked the recoil could naturally not be applied here, and yet it was clear to every one that a proper recoil check was the main point in the problem to be solved, because the stability of the gun was the one primary condition. In 1890 a trial by way of general investigation was carried out with an 8-cm field gun, which was supposed to reach the upper limit of the efficiency of a field gun of this caliber. It was given an initial velocity of 597 meters and obtained with its projectile weighing 7 kilogrammes 127 meter tons muzzle energy. Krupp continued the trials during the next year with two 6-cm quick-fire guns L/30 and L/38 respectively. The arrangements for checking the recoil for one was a lamellar brake, for the other a nave disc brake. Both had a fixed spade under the trail, as well as a swivelling upper carriage, which permitted slight corrections of the lateral training without having to disengage the trail spade deeply embedded into the soil. These guns indeed did not recoil, but jumped forwards when fired, losing the direction. But even under these circumstances a quick fire of 8 to 9 rounds a minute with good hits was obtained, a remarkable result for the time being. The Prussian Ministry of War, by these results, was induced to order from Krupp a quick-fire field gun for trial, that had to answer certain requirements. From the experiments carried on so far, the Krupp factory had gained the conviction that the stability of the gun during fire could not be ensured by checking devices alone, but that above all the shock on the carriage had to be diminuished. For this reason a quick-fire field gun 7·5 centimeter with small recoiling upper carriage was put to trial about the middle of 1892, but still, the gun when fired jumped 30 to 40 centimeters high and to the side. In the meantime, towards the end of 1890, Krupp had tried with very good success a 12-cm naval gun L/40 placed in a cradle mount. This cradle was a bronze sleeve fitted with lateral trunnions and served as a guide for the gun during recoil and return to battery. Underneath the cradle, brake and recuperator springs were fitted. The cradle introduced into the building of carriages and mounts an element of construction, which is on a par with the smokeless powder as regards its importance in the development of the quick-firing gun. When recoiling, the cradle forces the gun to recede in the direction of the axis of the bore, that is in the direction of the gas pressure. There is therefore no vertical component of the shock of recoil, which with upper carriages that move up a sloping slide, exerts all the more strain on the lower carriage the greater the elevation of the gun is. The first to profit of this advantage were the coast-defence and naval guns, the chassis and substructure of which were relieved by the arrangement. The reduction of the strain on the carriage or mounts made it possible to apply the improvement also to carriages on wheels, because they could be made longer and thereby gain in stability, and yet be of lighter structure. Howitzers and guns of siege ordnance with carriages on wheels and recoiling on their carriages have indeed only become possible on this foundation. Also the wooden platform, indispensable in former days for siege guns, could be dropped after the cradle had been adopted. A further advantage to be mentioned is that the sighting arrangements can be applied independent of the gun recoiling during fire, by being fitted on the cradle, from which follows that also the laying of the gun can be done independent of its loading, which again enhanced the rapidity of fire. So the use of the cradle has brought about an utter revolution in the design and in the application of all kinds of guns.

After the above mentioned trial of a field gun with recoiling upper carriage had not given satisfaction, a new gun placed in a cradle assuming the shape of a sleeve which with the upper carriage could be swung round for lateral training, was put to the test in 1892, it was given a recoil of 310 millimeters, fitted with an hydraulic recoil-checking brake, recuperator springs and a spade fixed under the trail. It is the first gun-recoiling field carriage which had all the features of the construction that have remained valid up to the present, viz: recoil of the gun guided by special guiding arrangements, an hydraulic brake to check it, a recuperator spring set by the energy of recoil, lateral training gear and a brake spade under the trail. The experience derived from these trials was that absolute stability of the gun could only be attained when its recoil was many times longer. It was feared, however, that such guns would be too complicated, too little enduring and too heavy for field use. This opinion was much corroborated by the results so little encouraging that had been carried out first at the Grusonwerk and soon after, in the summer 1893, also in Essen, with two field guns of 6·5 and 8 centimeter caliber respectively, both designed by the engineer Haussner, at the Grusonwerk. The one was permitted to recoil 1·17, the other 1·44 meter. The opinion expressed coincided with that prevailing in military circles as well as more particularly among technical experts of artillery, which was, that the long recoil was unfit for field use. In order to ensure stability of the gun during fire and consequently to avoid bringing the gun into the firing position again after every round, the works first took up another principle which was founded on the observation that a big spade fastened under the trail of the carriage formed a sufficiently solid abutment against the stress of recoil, if only the recoil was checked by an elastic brake arrangement. At the same time it should be possible to accumulate sufficient force to run out the gun back to the firing position. A construction, which may be called one of transition, thus originated in the spring 1894, the sides of the carriage of this gun were formed of tubes that telescoped and had a spring inside it, which was compressed during recoil and by its expansion ran out the carriage. The gun tube was fitted with two vertical trunnions, the bearings for which were provided in the centre of the axle of the carriage, which arrangement, yet with one single vertical pivot, was applied to the gun C/96 of the German field artillery. The telescope carriage was eventually followed by a number of other designs with an elastic spade, the latter assuming its highest degree of perfection about the beginning of 1897, in the shape of the swinging elastic spade. The Krupp works received a considerable number of orders from different states for guns with such a spade. In the meantime they had not neglected to continue developing the use of the long recoil for field guns, and good results had been obtained in 1898 and 1899 with field gun carriages on which the gun could recoil 1200 to 1300 millimeters, and which in order to increase the stability, had been raised in lenght from 1400 to 2300 millimeters, the firing height also being considerably reduced. It was not yet possible at the time to make recuperator springs that would allow of sufficient compression to equal that of the whole length of recoil, and it was necessary to reduce the stroke of the compression in proportion to that of the recoil by the use of a transmission. In a construction dated of the year 1899 a pulley was introduced which established a ratio of one to two for these respective lengths. Towards the end of 1900 Krupp succeeded in manufacturing recuperator springs from wire of oblong section, which, when compressed, were so reduced in length that for a recoil of 1300 to 1400 millimeters, it was possible to use a one single column spring, which had undeniable advantages over springs telescoped into one another. In 1901 the cradle adopted the shape of a box closed on all sides, in which was placed the hydraulic brake cylinder that had the recuperator spring passed over it. The edges of the upper face of this box were taken as guides for the gun tube, which was held on to them by claws fitted on three hoops shrunk on the gun. To its lower face a vertical pivot was fitted which engaged in the upper carriage or cradle carrier, that took the place here of the pivot support, and was lodged by trunnions in a lower carriage. The cradle could be traversed about this pivot together with the gun tube, for a lateral adjustment of $3^1/_2$ degrees to either side. As the gun was perfectly stationary during fire, it was possible now to protect the men by an armour shield against infantry and shrapnel fire, this shield went from wheel to wheel. Seats for the gunners were also fastened to the outside of the carriage body, one for the pointer and the other for the man attending to the breech. In this form the Krupp field gun had obtained in 1902 the fundamental features which it still possesses. Krupp field guns of 7·5 centimeter caliber fired projectiles weighing 6·5 kilogrammes, and gave them an initital velocity of between 500 and 585 meters. The muzzle energy thus produced varied between 83 and 113 meter tons. In order to get all the benefit to be derived from the firing speed, the ammunition wagon was no longer placed at a distance from the gun to its rear, but close to its side, it was so arranged that not only the face turned to the enemy, but also the opposite side, which was opened in the fashion of a double door when cartridges were taken out, consisted of armour steel plate. One single continued protecting armour was thus obtained after the gap between the gun and the ammunition wagon had also been filled up by a special shield, provided with a slit for observation. The entire attendance of the gun finds shelter behind this shield. The ammunition wagons manufactured by Krupp are on two systems. The ammunition box of the one is arranged for being tipped, the other not. In the former the cartridges are placed upright, in the other horizontally. A fuze-setting apparatus is fitted to the wagon; this device has been improved in various stages since 1902, and has greatly helped to increase the firing speed. Of late an elastic device inserted in the connection between limber and carriage, softens the shock at the moment when the horses begin to pull. Observation ladders protected by an armoured shield have also been introduced, to be able to observe the fire from a sheltered battery. These are transported either together with the ammunition wagon or on a special carriages.

After the field guns had received the system of recoil on the carriage, now came the turn of the mountain guns, For the design of this gun two requirements have to be fulfilled that are in a certain sense opposed to each other; great efficacy of the single round on the one hand, and the least possible weight of the gun on the other, which must permit besides of being taken apart to make up as few loads as possible. A compromise therefore is necessary between caliber and ballistic efficiency for this gun more than for any other. The requirement of a high muzzle energy, which means long gun tubes, being given, take-down gun tubes were constructed by the Krupp works as early as 1877, the trunnion hoop of which formed a connecting sleeve between a front and a breech piece of the gun. The higher ballistic effect of such long guns, moreover the requirement of keeping the largest possible horizon under fire, and particularly that of a great angle of depression claimed also a carriage of greater length, and one which could be taken into parts. A carriage of this kind, the trail part of which could be pushed between the sides of the front portion, was built in 1880. All these questions now turned up again, when the higher efficiency and the increased firing speed, that were obtained by the application of the long recoil, had to be applied to mountain guns also. Beginning from 1901 a series of model designs were produced at the Krupp works, of mountain guns with long recoil, they varied in calibers from 5·7 to 7·62 centimeter with lenghts of guns from 14 to 20 calibers. Afterwards also 10-cm mountain howitzers were built. Their gun tubes had 14 calibers in length and were either massive or built-up on the jacket system. Long tubes are arranged to be taken apart. Instead of the junction by way of a sleeve, an arrangement has now been adopted by which the jacket is slipped over the inner tube and the two pieces are connected with one another in the way of a bayonet. The jacket is fitted with the horizontal wedge mechanism with crank action, or the screw plug, both being now fitted for automatic working. As the gun tubes of mountain ordnance are generally short, they had to be fixed on an intermediate slide, which with the gun recoils along the cradle. Mountain guns have a far higher limit of elevation than field guns, at least 30 degrees as compared with 18 degrees. Also in the interest of their stability their height of fire must be taken less, if not the length of recoil and of the carriage are to be increased beyond reasonable dimensions; it is not possible with these guns therefore to preserve the same length of recoil, or the same firing height for greater elevations. In consequence Krupp has adopted for his mountain guns either the automatic variable recoil, or a cranked axle which may be ajusted accordingly; if the elevation goes beyond 20 degrees, the crank of this axle is turned upward whereby the firing height of the gun is correspondingly increased, so that the same length of recoil can be taken even for the highest elevation. The other arrangement consists in a device fitted in the hydraulic brake, which gradually reduces the length of recoil in proportion as the elevation increases. The advantages and disadvantages of both systems nearly balance, and Krupp furnishes the one and the other, as is desired by the customer. The lower carriage either has two sides, or is shaped like a box, it can be taken to pieces into a front part and a rear portion, the latter is fitted with a rigid spade or with a small spade for rocky soil, or again with a big folding spade. As the track of mountain guns is narrow, the protecting shield goes beyond the wheels on either sides, so as to afford sufficient shelter for the men. To transport the gun 4 to 6 beasts are required, but it can also be drawn by beasts without the limber by means of a shaft inserted into the trail.

In 1907 the Krupp works began experiments with the differential recoil, which, theoretically speaking, means the highest stage of development of the gun recoiling system. With the system of differential recoil the gun, the moment it is fired, is given an energy propelling it forward, by means of compressed air or by springs, these forces having been accumulated during the previous recoil. The recoiling energy of the gun therefore is diminished by the propelling energy, the former therefore is less than if the gun had been fired when in rest. The great theoretical advantages of this system are apparent, and Krupp has built mountain and field guns with various modifications on this system. But extensive firing tests have proved that this system is still attended with many imperfections, that outbalance its advantages, the chief one of which is, the want of reliable accuracy of fire. The reason for this is, that the forces which propell the gun forward, also react on the lower carriage, so that the whole gun, even before the projectile leaves the bore, is forced out of its direction, more or less, according to the nature of the ground. And so far it has not been possible to overcome the disadvantages of the differential recoil system in a satisfactory measure, Krupp therefore does not consider himself justified yet to recommend it for adoption.

When in field warfare shelters were getting more and more used, field howitzers were called to act the part which siege and garrison howitzers had long been called upon to take. This was reason enough, to let these guns also benefit by the technical advancements that had been applied to field guns. The first field howitzer with gun recoil that Krupp made, had 11 centimeters caliber, and was exhibited at Düsseldorf in 1902. As the three forms of application of howitzers in field, garrison, and siege warfare imply, in a general way, the same requirements, the same principles of design have been applied to all kinds of howitzers. For all of them the gun tubes had to be made longer, for mortars as well as howitzers, because the conditions of fighting in modern times demand greater ranges. Krupp recently has called all curved-fire guns "howitzers" because the characteristic differences between mortars and howitzers, *i. e.* the length of the gun and the limits of elevation, have been more and more obliterated. Krupp has built howitzers of all calibers from 10 to 40 centimeters, with lengths of the guns varying from 12 to 20 calibers, according to their particular destinations. All howitzers to be used in field and siege warfare have carriages on wheels, and are arranged to recoil on the carriage, their breeches are fitted for the use of metal cartridge cases. For calibers upwards of 15 centimeters the recuperating energy is provided by compressed air, for smaller calibers, springs are used, these being the simpler device. Besides the system of variable recoil, which has already been spoken of, Krupp has worked out for howitzers one in which the trunnions are placed right to the rear of the cradle. He began to develop these systems in 1905. In its plainest form it had already been tried towards the end of the 'eigthies at the Grusonwerk. When great elevations are taken, the breech end of the piece with the ordinary position of the trunnions, went right down between the sides of the cradle, and very close to the ground. If, on the contrary, the trunnions are placed right back, then the position of the breech end nearly remains the same for all elevations; uninterrupted loading is therefore possible in any position of the gun. Besides, even with the highest elevations, the recoil of the gun may be comparatively long. The very complicated arrangement for the variation of the recoil can therefore be avoided, and the pressure on the carriage at great elevations can be reduced to a fraction of that excerted by the same gun with variable recoil. There is this slight drawback which deducts from these advantages, that an arrangement is necessary to counteract the forward preponderance of the gun with a view to facilitate laying the gun for aim. In cases where the greatest possible stability is required even for slight elevation, which stability can only be secured by an extraordinarily long recoil, the two systems, the variable recoil and the rear trunnions, are combined. All howitzer carriages on wheels are provided with protecting shields, seats on the carriage, folding or rigid spade, and can, the same as field guns, fire on any ground without platform. To prevent the wheels from sinking into the ground during fire, in most cases wicker mats suffice for small calibers, heavy howitzers from 21 centimeters upwards, are fitted with rail girdles composed of rail pads linked together, which, as two or three together are always between the rim of the wheel and the ground, afford a large supporting surface for the former. It is a device invented by the Italian major Bonagente, who took out patents which Krupp bought in 1906. These girdles also have become an expedient almost indispensable for moving guns on soft ground. To make heavy ordnance transportable, the following arrangement besides has been adopted, one by which the gun tube is transported on a special wagon, with calibers of upwards of 21 centimeters. The upper frame of this wagon is provided, like the cradle of the gun, with a sliding face for the guiding claws, so that the gun tube can easily be drawn off the carriage on to the special wagon, and vice versa.

In the siege and fortress warfare of the future, the main part will be assigned to the howitzers, although for certain objects, there too, guns will remain indispensible, these therefore have also been built on the gun-recoil system. This proved to be all the more necessary, because in consequence of the ranges being considerably increased, the ballistic efficiency of siege guns also had to be augmented in proportion; and this again meant an increased strain on the carriages. With the long recoil it was possible to keep the weight of these carriages within such limits that they remained carriageable. The system besides did away with the wooden platforms formerly required. Guns of this kind are manufactured by Krupp at present of calibers ranging between 7·5 and 15 centimeters. The length of the guns vary between 30 and 35 calibers, their muzzle velocities between 590 and 750 meters, and the ranges between 10,000 and 12,500 meters. The greatest elevations at which the gun can fire he, between 30 and 40 degrees; the muzzle energy for the 10·5-cm gun is 376 meter tons, it rises to 1176 meter tons for the 15-cm siege gun L/32. By way of comparison it may be remembered that the 15-cm cast-steel gun C/64 which was used in the sieges during the war in 1870/71, developed a muzzle energy of 131 meter tons. In their general arrangements, these siege guns resemble gun-recoiling field ordnance. They are generally given a recoil of 1·5 to 2 meters, so as to ensure good stability also at slight elevations. As the guns fire for long ranges at elevations of over 30 degrees, variable recoil is applied. For the transport of the gun properly speaking special carriages are used here too for the big calibers; the platforms are replaced by wicker mats and rail belts for the wheels.

After count Zeppelin had been so successful in 1906, one was justified to assume that in future wars the dirigible airships would play an active and important part. So the problem was taken up by Krupp to design guns and appropiate ammunition to fight these new weapons. The Krupp works had already in 1870 built a 4-cm balloon gun, to attack the free balloons that were sent up from Paris, but this gun was no use in the new warfare against modern airships, which were of a totally different nature. New means of attack therefore had to be invented which had to be in harmony with the nature of these aerial weapons. Above all, the new gun had to be given a great mobility; it had to be of light weight, and able to quickly take high elevations and to follow constantly the movements of the aim. Such mobility of the gun could practically be obtained either by placing it on a motor car, or by giving it arrangements similar to those of horse artillery. Krupp has pursued the aim in both directions, and guns of either species could be exhibited as early as 1909 at the International Aeronautic Exhibition at Francfort-on-Maine. Both specimens shown there were guns of a well and thoroughly elaborated system. The gun tubes had rear trunnions, automatic vertical breech block, they could be traversed right round through a circle, and take elevations of up to 75 degrees. The gun mounted on a motor car is placed in a central-pivot mount. The gun carriage has been given an arrangement which allows the gun to be traversed right in a circle. For this purpose its trail spade is joined by a pivot to the trail, and the axle trees can move on hinges about the end of the carriage axle, so that the wheels can be so swung round for the traversing movement that they describe a circular line, the centre of which lies in the trail pivot. As the gun is able to fire in this position, it is possible to follow the movements of the airship very rapidly, to which helps the device that the upper carriage of itself can be laterally trained by five degrees to either side. The spring to compensate the forward preponderance of the gun lies in the pivot of the upper carriage. The fuze of the high-explosive shell is so sensitive that it detonates immediately after it has touched the cover of the airship. To facilitate observation the projectile contains a smoke producer which is ignited the moment the gun is fired, and which all along the trajectory gives off smoke, which allows it to be traced in the air. The latest Krupp guns of this kind are the 7·1-cm and 7·5-cm field guns for horse artillery. Besides their destination to attack airships, they can also be used as ordinary field guns. Besides the guns to be used in field warfare Krupp has also built guns for similar purposes of 10·5 centimeters caliber in central-pivot mount for naval, coasts defence, and garrison artillery.

As a rule, the stationary guns in fortresses are protected against curved fire by armoured shelters, and when visible from afar, also by a glacis armour to protect them from fire attacking them from underneath. In cases where the object of these guns does not require protection against curved fire, they are mounted on central-pivot mounts with armour shields, such as are used for coast-defence and naval mounts. Armoured turrets for inland fortifications mostly have one gun only, sometimes two, and are fitted with minimum embrasures. The turret with a cupola roof made of rolled nickel steel is traversed on rollers or balls, its turntable lying within a glacis armour. Sometimes the gun also is placed in a mount which is rigidly connected with the armoured cupola, and therefore cannot recoil. The whole system is then traversed on a central pivot column. This armoured mount as well as the disappearing turret, which is only raised above the glacis armour the moment it is fired, the same as the armoured turrets on wheels for small calibers, are constructions due to Schumann, of which more will be said in connection with the Grusonwerk.

About the beginning of the 'nineties, Krupp started his armour plate mill, and began to furnish armour for the battleships of the German Navy; this led him to take up also the building of armoured turrets and naval mounts with all their arrangements for use on board. This sphere of activity of itself developed a cooperation of the Cast Steel Works with the Naval Authorities for the development of all constructions that presented themselves. When quick-fire breech mechanisms where adopted for the bigger calibers of naval ordnance, improvements became necessary of those arrangements the object of which is to raise ammunition from the magazines below, and to bring it right up to the gun, because on this the loading speed essentially depended. The great importance which attaches to these arrangements explains the long series of phases of their development as well as the constant desire to improve them. Hand-working at the same time had to be supplanted by mechanical devices both for the movements and the attendance of the guns. During the 'eigthies Krupp applied hydraulic motive power, which during the 'nineties was exchanged for electricity, in conformance with the tendency of the times. The hydraulic force was generated by a steam pump with automatic governing device on the Krupp system; the voltage for electric working was regulated by a special system. It was about this time that the cradle was adopted, as has been said before. The ammunition hoists for the guns firing "en barbette", were in those days outside the turntable, so that the ammunition had to be taken to the gun. This implied a loss of time, which was remedied by joining the hoisting apparatus inseparably to the turntable. It thus followed every movement of the gun for lateral training, so that the ammunition when hoisted always landed near the breech of the gun, this construction became the fundamental basis for all subsequent increase of the firing rapidity. There was another advantage inherent in the system, the turret could be given a smaller diameter, and the ammunition hoist was placed inside the armoured pit which also protected the mechanical arrangements for the working of the turret against hostile fire. The lifting apparatus for the ammunition took the shape either of hoists or paternoster works which raised the ammunition either upright or in an horizontal position, from the shell and powder rooms to the breech of the gun, where they were placed on a loading tray. The mode of securing a regular and quick supply of ammunition with a view to increase the loading speed, has undergone many modifications in the course of time. In 1897 Krupp built an elevator which mainly consisted of a rod fitted with pawls, which, as it moved up and down, lifted the ammunition step by step from one pawl to another of the hoist shaft, and when the topmost projectile arrived aloft, it was tipped over into the loading tray. This system was much applied for casemate guns on account of the little space it required. The modern ammunition hoists of armoured turrets lift the shell together with the cartridge case in an horizontal position, and let it roll out on to a loading tray which can swing over and lands behind the breech of the gun, whereupon the shell it is rammed home into the cartridge chamber. With the object of further increasing the firing speed, a second space with a certain supply of ammunition has been provided, within immediate reach of the gun and from which ammunition can be quickly raised to the breech. This space is supplied from the ammunition magazine properly speaking, and is fed by its own hoist. The use of the loading tray implies a fixed and certain elevation of the gun for loading; it is therefore necessary to return the gun each time from its elevation for range to that of the loading position. Recently an arrangement has been designed in which the hoist drops both shell and charge into a loading tray, the height of which automatically adjusts itself to any elevation of the gun, so that ramming home can be carried out at any elevation, because the rammer likewise adjusts itself simultaneously in height, and also for the shorter second stroke to ram home the cartridge case. As only little room is left behind the guns in armoured turrets, the ramming rod is built on a telescope principle. Less room still is taken up by a chain rammer of quite recent construction, it consists of a chain passed round a driving wheel the links of which are so constituted that when uncoilod they form a rigid and straight bar.

Krupp coast-defence guns have developed on the same general lines as naval guns. But as the former are not subject to any limits of weight, also chilled cast-iron revolving turrets are used in coast defence, besides chilled cast-iron batteries, at such points as are supposed to keep a wide horizon under fire. Both turrets and batteries are built at the Grusonwerk. In modern times armoured turrets with cupolas made of rolled and pressed nickel steel plates are preferred to the chilled cast-iron turrets properly speaking. All armoured turrets are encircled by a glacis armour above which only the flat cupola and the muzzle of the guns are visible. The latter are placed in cradle mounts with minimum embrasures. Just as with naval turrets, the cylindrical pit is arranged below the turntable. It contains the ammunition hoist and the mechanical arrangements for the training of the turret, and the elevation gear. Such turrets are as a rule for two guns.

Centre-pivot coast-defence mounts, protected by a curved armour shield open at the back, were built by Krupp towards the end of the 'eighties. They could boast of the advantage, as compared with the front-pivot mounts in use up to then, of affording protection for the ammunition hoist. In countries outside Germany guns on disappearing mounts were also used for coast-defence; Krupp has turned his attention also to this kind of gun. Its main feature is, that the gun by the action of the recoil energy is swung back and down into the covered loading position, and is raised again above the breast work by the force accumulated during recoil. While offering safe shelter to both gun and men, they are cheaper than guns in turrets. The first disappearing mount for a 12-cm gun was built by Krupp in 1889, it was a siege and garrison gun which was carrigeable, and could be mounted on a platform previously prepared, as well as on a railway truck arranged for the purpose. The accumulator for this gun was a compressed air reservoir which communicated with the hydraulic recoil brake. In 1900 a disappearing mount with counterweight was constructed. The gun is fitted on a turntable that stands on a ball race, and thus can be traversed for lateral training. When the gun is fired the frame carrying it swings backward, thereby raising a weight which acts as an accumulator of force, at the same time an hydraulic brake is worked which is connected with an automatic valve that retains the gun in its lowest position. After the gun has been loaded and laid, the valve is opened, whereupon the gun rises automatically, and when arrived at its highest point, it is automatically fired by an electric contact. A disappearing mount of this kind for a 21-cm gun L/40 was exhibited at the Düsseldorf Exhibition in 1902. Since that time Krupp has delivered a large number of such gun mounts for calibres ranging from 15 up to 28 centimeters.

Alongside of a greater firing speed, it was necessary also to obtain greater accuracy of fire, the laying gear therefore had to follow suit to the improvements of the guns, their breech mechanisms, and mounts. The old open sights that had been in practice ever since the beginning of artillery, could hardly avoid inaccuracies of laying, springing from various reasons. It was therefore impossible with these to utilise fully the accuracy liable to be derived from rifled guns, which indeed were instruments of precision. In 1890 the Krupp works fitted the sight bar with a spirit level which permitted to ascertain the angle of sight, after the gun had been laid by means of the rear and front sight. After adjusting the sight bar, the elevation for range could be very accurately taken. The sight bar, which hitherto had been straight, took the shape of the arc of a circle, the centre of which lay in the axis of the trunnions. It was at the same time given an oblique position corresponding to the normal deflection, so that the rear sight had only to be shifted laterally when wind or other causes influenced the lateral drift. Soon after, a second spirit level was added, and an arrangement to eliminate the error due to the difference in the levels of the wheels. These devices formed the foundation upon which are based all the improvements of the sighting gear down to the present day for gun carriages on wheels. A further fundamental improvement took place in 1899, in consequence of the ever growing ranges, when a sighting telescope was adjusted to the sight bar. As now the line of sight was determined by the optical axis of the telescope, the front sight which had hitherto been the medium point to determine the line of sight:—rear sight, front sight, aim,—could be dispensed with. Thus a frequent source of errors was supressed. The collimator which formed a sort of transitory device leading up to the optical line of sight, as determined by the telescope, yet without any optical magnifying, had been taken over by Krupp from France. This device also does not need a front sight, and allows of taking aim more correctly than the old system by rear and front sight. It has been improved upon by Goerz, and is still in use for quick reconnoitering of the aim, or also as an emergency sight. The ordinary terrestrial sighting telescope was in 1900 supplanted by the Porro prismatic telescope which is less sensitive to vibrations. A lasting application of the telescope, however, only became possible, when the gun recoiling system permitted to fit the sighting bar to the cradle. In 1901 a graduated disc, the azimuth circle, was added to the telescope sight bar which, when firing under cover, permitted laying the gun by means of an auxiliary mark. A further improvement in this line took place, when the Corrodi-Goerz panoramic telescope was introduced in 1903, which permitted of laying at an auxiliary aim at any point of the horizon, without the pointer having to change his seat behind the telescope. For field and mountain guns the independent line of sight then came into use. By this, the work of laying, aiming, and setting the sight bar can be divided between the pointer and the servant attending the breech mechanism, which again means raising the firing speed. The sighting gear for howitzers is constructed on the same general lines as that of field guns. For field howitzers, however, with a constant long recoil, the rear position of the trunnions, has entailed some peculiar modifications of some of its parts. It was needed here to give the sight bar a very strong curve, which did not permit to make the graduation for field use sufficiently legible. This led to the introduction of the drum sight. The graduation is engraved of the face of a drum, which moves simultaneously with the sight bar. Further mention must be made here of the sector sights for mountain guns and the sighting devices with indicator for howitzers to be loaded at a certain position of elevation. Siege and garrison guns were provided with similar sighting gear as the field guns, as soon as they too had adopted the gun recoil system. Generally speaking the guns are provided with an emergency sight and then have the old front sight.

Naval guns also were laid in older times with the naked eye by means of rear and front sight. The introduction of cradle mounts also brougt about a change here, which was necessitated by the demand for greater firing speed and longer ranges. The consequence was the adoption of the telescopic sight. As regards the increase of firing speed there were two moments to be considered, the setting of the sight bar to the required elevation had to be facilitated as much as possible, and the various operations involved had to be divided among several men. As only direct laying comes into question on board, spirit levels, azimuth discs, and panoramic telescope are of no use here. The only question is, to adjust the sight bar for range, and for the various kinds of projectiles and powder charges. To facilitate the adjustment, the graduation on the sight bar was made distinctly legible, the sight bar was given a curve forming an arc of a circle, and in order to elimate deflection for normal conditions was placed obliquely. A division of labour is effected in this way, that one man lays for lateral training, the other for elevation. The latter follows the rolling motion of the ship with his gun, and as he simultaneously watches the lateral training, he can fire at the right moment. The laying gear of coast-defence guns corresponds in a general way to those of naval guns, those of coast-defence howitzers to the sighting gear of curved-fire guns for land ordnance.

The ballistic efficiency finds its real expression in the effect of the projectile, for the object of artillery fire is, to give to the projectile an intended effect when it strikes the aim. The energy developed by the combustion of the powder charge works on the projectile which propelled by it, is supposed to perform work at the distant aim, pierce armour, penetrate into earth works, walls and such like, or work other effects by means of its kinetic energy. At the goal it is supposed to have effect either by the detonation of its explosive charge, or in case of the shrapnel, by the bullets it contains. So the problem arose to fulfil the requirements that became more and more diversified as regards the different effects of the projectiles, apart from the question of raising the ballistic energy of the gun. The growing resisting power of naval armour demanded to give to armour-piercing shell a higher resistance to the shock on impact by improving the steel and the modes of their manufacture, so that without being deformed, they might pierce the armour, and have their detonating effect inside the armour protected chamber. After nickel-steel plates hardened at the front face had been introduced towards the end of the 'nineties, which commonly shattered the armour-piercing shells on impact, the perforating power of these shells was increased by applying a cap to their point, which was made of mild tenacious steel. The bursting effect of the projectiles has been raised in the course of time by applying more powerful explosives than ordinary black powder was. High explosives are now used for the armour-piercing and explosive shells fired from naval guns, also for ordinary explosive and torpedo shells, which are used in garrison and siege warfare. The body of torpedo shells is very thin of metal, so as to obtain as large as possible a cavity for a big bursting charge, and yet to keep the projectile sufficiently proof against shock. The steel body of explosive shells is thick of metal, because they are supposed to act not only by their bursting effect, but also by the kinetic energy of their fragments. They are fitted either with a percussion or double-acting fuze or with a retardation device, liable to be switched off or on, so that the bursting charge may be made to act after the projectile has penetrated into the aim to a desired depth. For objects of particularly great resistance, explosive shells are given a hard point, and are fitted with a bottom fuze, whereas torpedo and ordinary high-explosive shells commonly have the fuze at the point. The Krupp shrapnel is a steel case, thin of metal; it is fitted with a rear bursting chamber for the charge, and a double-acting time fuze or a mechanical fuze; in the former, the time of flight from the muzzle until the bursting point is determined by the conflagration of the powder composition, with the latter by a kind of watchwork. This mechanical fuze, the invention of the watchmaker Bäker, has been essentially improved by Krupp after many years' trials, and has since been sold in large numbers to various states. A few years ago Krupp began experiments aiming at a single type of projectile, which was supposed to combine the effects of the shell and the shrapnel, and which is therefore called "shrapnel shell", the bullets are imbedded in an explosive which when the projectile is fired for percussion, detonates and helps to increase the shell effect, and the shrapnel effect on the other hand is enhanced by the shell part which is propelled forward from the bursting point, and which on impact bursts in consequence of a percussion fuze fitted to it. This universal projectile is of very great importance for field artillery, as it helps very much to simplify the supply of ammunition in warfare. But single type projectile are also manufactured by the Krupp works for siege and fortress warfare.

To finish up this description of the evolution through which gun manufacture passed at the Krupp works, a short retrospective survey of this development may be given. Taking the year 1851 as the beginning of Krupp's carrer as a gun manufacturer, when he for the first time attracted the public attention by the exhibition of a 6-pounder field gun in London, 60 years have elapsed now. The first ten years contributed little to the fulfillment of those hopes which Alfred Krupp had placed on this branch of manufacture. Gun manufacture "en masse" only set in about the beginning of the 'sixties, when rifled guns became universally adopted. The way in which afterwards Krupp's reputation spread all over the globe, may be seen from the fact that he furnished guns to 52 different states excepting the German Empire and its federate states:—23 in Europe, 6 in Asia, 5 in Africa, and 18 in America. Down to the end of the year 1911, orders have come in from these for altogether 27,300 guns; the German Empire, for the German Navy, and the different federate states now united in it, have altogether ordered 26,300 gun tubes, to that the sum total of gun tubes ordered down to the end of 1911 amounts to 53,600 in round figures. Of these 50,000 had been delivered until the beginning of June 1911. The year 1898, with 3177 gun tubes stands first for the number of guns ordered in one year; taking it by the size of calibers, the orders of late years essentially are in favour of the big calibers, in agreement with the development of the naval forces.—One is justified to put the question, how it was that Krupp could be so successful as a gun manufacturer, although from the very beginning down to the present day he has constantly had to fight with competitors. It must be remembered besides, as a circumstance to his disadvantage, that the competition in many cases offered to furnish at considerably lower prices. It has frequently been suggested to Krupp, when he commenced as a gun manufacturer, to use a less precious and cheaper cast steel for his gun tubes, as it was not necessary to make guns of steel of such high quality, as he did. This advice, however, Krupp resented as an insinuation, that he could not make to agree with his principles. On the contrary, he gave strictest order to his works only to use the very best steel, of irreproachable quality, for guns, and to reject, regardless of any consideration, every gun which in the course of machining should show deficiencies that could not pass. These Alfred Krupp's instructions form a legacy which, down to the present day, has been considered an unimpeachable law, and so the improvement of gun steel, of gun design and of the arrangements belonging to the gun, have at all times at the Krupp works been most carefully attended to, the same as has been the examination of gun tubes and of objects of ordnance all through the course of their manufacture. The strictest observation of these principles have esentially contributed to build up that confidence, which the Krupp works have gradually acquired on the part of their customers. By constantly adhering to the old approved tradition, and by incessant progress on all domains of gun manufacture, the works will continue to endeavour in the future, as they have done in the past, to keep up this confidence undiminished.

# ON NEW PATHS.

The continued evolution of the Cast Steel Works after Alfred Krupp's death proves that his successor had the ability as well as the desire, not only to manage his enheritance, but also to enlarge and extend it with the necessary energy. Much of what has been called into existence since 1887 was certainly the natural result of former enterprises, much had already,—as in the case of the new iron works—been indicated or attempted by Alfred Krupp. But in the realisation of such plans to which Friedrich Alfred Krupp devoted his special attention he had gone considerably beyond the original projects. This in particular was the case with the armour-plate rolling mill; here, however, extraneous circumstances also played a part. From 1876 onward, the German Navy had used none but armour plates of home manufacture—at first supplied by the Dillingen iron works. Until 1880, these works only made forged-iron plates; after that time, compound armour plates of the Wilson patent pattern, and they were quite in a position to supply the entire demand—small at that time—for the German Navy. Soon after the accession of Emperor William II, however, a new naval policy was inaugurated, which, after a rather long pause in the building of battleships, aimed at an increase of the fighting strength of the Fleet. It now seemed advisable to raise the efficiency of the home manufacture of armour in proportion to the expected demand for armour plates. These circumstances caused the Imperial Admiralty to repeat the often expressed wish that the Krupp firm would take up this branch of production. Friedrich Alfred Krupp, though he did not underrate the difficulties of the undertaking, resolved to respond to the call, and to realise the plan of a great armour workshop which should suffice for all the expected orders. The first thing required was the armouring of the battleships of the Brandenburg class, and Krupp undertook to deliver the plates for the 'Wörth' and the 'Kurfürst Friedrich Wilhelm', while the making of the armour for the 'Weissenburg' and the 'Brandenburg' was handed over to the usual manufacturers, the Dillingen Ironworks. To this end the rolling mill was designed and erected with all possible haste and started in 1891. This extensive building, which was combined with the pressing plant erected at the same time, was intended exclusively for the making of compound plates—the only ones used at that time in the German Fleet. Its equipment consisted of a powerful rolling mill with rolls of 4 meters useful length, and a diameter of 1·2 meter, worked by a reversible engine of 3500 horse powers, regenerator welding furnaces of the largest dimensions for welding the heavy wrought-iron back plates, and an acid open-hearth furnace for casting the hard steel layer on to these back plates. There were big heating furnaces for heating the compound plates ready for rolling, and hydraulic bending presses of 7000 tons pressure for beending the plates to the form required. The shops contained a number of cold-sawing, planing, milling, slotting, drilling and boring tools of the largest description for machining. Thus the newly erected shops contained all that was needed for making the heaviest compound plates, with the exception of the materials required for the back plate. These were produced in the puddling shop and plate-rolling plant; the puddling shop produced the billets or rough-rolled bars of the toughest welded iron which were then made into piles and passed to the plate-rolling mill, to be rolled out into so-called "covers", *i. e.*, plates of about 30 millimeters in thickness and 1·3 meter in length and width. These covers again were then laid in piles of the required number, brought up to welding heat, and rolled out into larger covers, which were measured off to the size required for the armour plate, that is, 2 meters to 2·5 meters in length and breadth and 10 to 12 centimeters in thickness. These big covers finally were made up in piles of 8 or 10, according to requirement, welded, and rolled out into the back plate, the thickness of which might be as much as 60 centimeters. The back plate was then cut to size, and heated white-hot, and a layer of hard steel of half its thickness was cast on. The compound plate so produced was again brought up to forging heat, and rolled out to the required thickness.

As has been shown above, the Krupp factory was by no means unprepared to enter on the manufacture of armour plates. The experiments made in Alfred Krupp's lifetime to produce armour plates by various processes, and of various kinds of iron and steel, had been continued by F. A. Krupp. In 1887, several wrought-iron compound plates had been made with a layer of chrome-steel welded on and hardened by a spray of cold water; these had behaved very well under firing. In 1888, some homogeneous chrome-steel plates, which had been subjected to a peculiar hardening process, had shown equally good results. From these experiments the conclusion had been drawn that the homogeneous chrome-steel plate and not the compound plate, was the armour plate of the future, for though the compound plates manufactured for the 'Wörth' behaved very well under firing—better indeed than those of any other works—still one was convinced of the possibility of producing homogeneous steel plates with a far greater power of resistance. They must, indeed, be so tenacious that they did not crack under the force of impact of a projectile, or split up into pieces, as the French plates made entirely of steel did. So, while producing the regular compound plates, the factory was continuing to make experiments in the direction of a resisting homogeneous steel plate. The trials with nickel-steel alloys, which Krupp had been making for years, resulted, in 1890, in the use of nickel steel for gun tubes. The excellent physical qualities which this steel showed here, made it advisable to try such an alloy for armour plates also. The experiments, begun in October 1890, were first directed to discovering the right proportions of nickel and carbon, and to the best process of making armour plates of these alloys. After good results had been obtained in the course of 1891 with nickel-steel plates of 240 and 270 millimeters thickness, a nickel-steel plate 400 millimeters thick, fired at the beginning of February 1892, proved so satisfactory that the manufacture of compound plates was quite given up, and the armour for the battleship 'Kurfürst Friedrich Wilhelm' was made of nickel-steel plates, 300 and 400 millimeters thick. This involved a complete alteration of all the plant for armour-plate manufacture. The appliances for the production of the welded iron covers and back plates, including the big welding furnaces, were now unnecessary. The acid furnaces were converted into basic ones, and the open-hearth shop plant was increased by building two 40-ton furnaces and one of 30 tons. The resistance of mild nickel-steel plates was 15 per cent higher than that of the compound plates. They displayed, indeed, such an extraordinary tenacity, that they did not crack even when the plate was thickly covered with shot holes. Still the question arose, whether a still greater hardness could not be given, so as to heighten the resistance to the penetration of the projectile. It seemed as if this were attainable especially in thin plates, and this was of importance as the plates of the ships of the Siegfried class, one of which was to be put on the slips every year, were to have 24 centimeters maximum thickness, while there was no prospect for the present of larger ships being built. The plates were made by selecting one of the harder kinds of nickel steel, the required toughness was obtained by a peculiar thermic process,—quenching in oil. The results of firing a plate of this kind were so satisfactory, that the building of plant was begun for the manufacture of such plates on a large scale. In order to accomplish the heating and hardening of these plates,—some of which were 10 meters long,—heating furnaces, and oil and water tanks of the necessary dimensions had to be provided. The great hardness of the new nickel-steel plates also necessitated alterations and additions to the appliances for machining. Plates hardened in oil were 10 per cent harder than the mild nickel-steel plates. They were used for all the ships of the Siegfried class laid on the slips in the following years; the 'Heimdall', the 'Hagen', the 'Odin' and the 'Aegir'.

However, the hardness already attained did not suffice to restore to the armour plate the superiority in its struggle with the projectile. Krupp himself had started the manufacture of steel projectiles for breech-loading guns in 1865, and had gradually made them so efficient, by improving the processes employed, especially that of hardening, that by the end of the 'seventies they pierced forged iron, steel and compound plates, with a scarcely perceptible deformation. During the 'eighties, projectiles were still further improved by the use of tungsten or chrome steel, so that they pierced even the plates hardened in oil without breaking. In order to obviate this, and to effect the destruction of such projectiles on their striking the armour plate, the face of the latter had to be hardened to a degree superior to that of the attacking projectile, or at least nearly approaching it. It was only possible to effect this by using steel very high in carbon, and hardening it in water. But if the whole plate were made of such steel, it would become too brittle, and would be shattered to pieces by the impact energy of the projectile. Therefore milder but at the same time tough nickel steel had to be chosen, which was high in carbon, and therefore capable of being hardened, on the front side only. So at the end of 1892, the so-called gas-cementing process was adopted, that is a process for the carburisation of the face of a nickel-steel plate by using lighting gas. The plate was heated for a time which in proportion to its thickness went up to 14 days, to a temperature of about 1000° centigrade, a continuous current of gas bring applied to its face all along. The gas, as it passed over the heated steel, decomposed and deposited carbon in a very fine state, which was absorbed by the steel, penetrating to a depth of from 40 to 50 millimeters, according to the duration of the process. It was now easy to harden this highly carbonised surface in running water. A plate prepared in this manner showed the requisite properties when it was fired in February 1893. A fired plate of this description, 260 millimeters thick was sent to the International Exhibition at Chicago in 1893, and proved superior to any plate hitherto produced in any factory, both as to resistance and tenacity. But there were certain defects even in this process, and the factory took advantage of a pause in orders for plates for the German Navy in 1894, to commence detailed experiments on a large scale, in the further improvement of these cemented and face-hardened nickel-steel plates. The first thing ascertained was that a steel alloy containing chrome as well as nickel is specially adapted to ensure a combination of extreme toughness with maximum hardness, even in the thickest armour plates required. The percentage of carbon this alloy contained was sufficient to make it capable of being hardened. The greatest possible hardening capacity was given to the front face by employing the above mentioned gas-cementing process. The whole plate was now brought up to the greatest possible toughness by a special thermic treatment, and then the front face only was hardened by spraying it with water at high pressure without destroying the toughness of the back of the plate. The face of such a plate was harder than glass, and the hardened portion, which went to about one third of the thickness, was shown to pass gradually into a tough fibrous texture towards the back. In December 1894, two plates 15 centimeters thick, made according to this process, were fired, and showed a remarkable superiority to all the plates previously made. Then in March 1895, another plate of the same kind, but 30 centimeters thick, was tested, and it was ascertained that the new process was as suitable to plates of this thickness as to thinner ones. The power of resistance was now as great as that of a compound plate of fully twice the thickness, and the tenacity was so great that the plate might justly be described as indestructible. In consequence of these firing results, Krupp plates made by this process not only became the regulation armour plates for the German Navy, but the patent for it was acquired by almost all foreign armour works, and is still in use at the present day. These are the armour plates generally designated by the term "Krupp armour" or "Krupp plates". The manufacture of these for general delivery was started in 1895, and necessitated another entire alteration of the workshops. Cementing, heating and hardening furnaces, and special appliances for hardening had to be built. The machinery, too, had to undergo a complete transformation. As none of the tools could bite into plates so hardened, they had to be finished by means of emery-grinding machines. The shaping processes were also no longer adequate, and they had to be replaced by others more powerful. The first orders executed for Germany were for the large cruisers, the 'Freya' and the 'Hertha', &c. Then followed orders for battleships of the Kaiser class, and the requirements of the present day are also supplied by these plates. The increased demand of recent years has necessitated a considerable enlargement of the armour plant, which has now at its command:—two rolling mills,—the newer one with rolls of 4·5 meters useful length and a driving engine of 10,000 horse powers,—three bending presses of up to 10,000 tons pressure, twenty-four cementing, heating and hardening furnaces up to 22 meters in length, five hardening plants, and eighty-six shaping machines. In the building which covers an area of 55,000 square meters, there are forty-two cranes, mostly electric, with a hauling capacity of up to 150 tons.

Since the introduction of the Krupp armour no important improvements have been made in the manufacture of armour plates, though all the factories in the world have been working at them, and though an increased power of resistance in armour is extremely to be desired. Until the beginning of the present century, the armour plate had a decided superiority over the attacking projectile, even though there had been great improvements made in the production of the latter, as the discoveries made in the production of nickel steel had been applied to the making of projectiles. But they were always destroyed when they struck, and so a great part of the force of impact was wasted. But after the introduction of capped projectiles, already mentioned, it was possible to shoot them uninjured through the plate, and this fact combined with the progress made in the manufacture of high explosives and suitable fuzes, again changed the relations between guns and armour plates in favour of the former. It is at present possible, at least if circumstances be not specially unfavourable, to cause the detonation of a high-explosive shell after it has passed through the plate. This gives back to the gun a conditional superiority over the plate.

The manufacture of special armour plates of complicated shape suggested the idea of casting them in a mould from the required steel alloy, and then giving them the external hardness. This idea, which Alfred Krupp had worked at as early as 1877, but without success, was taken up again in 1901/02 and carried into effect. At the Düsseldorf Exhibition of 1902 there were several specimens of armour made in this way among the Krupp exhibits, which, when fired, showed a power of resistance scarcely inferior to rolled plates. Thus the problem, which Alfred Krupp, who was always in advance of his time, had undertaken 25 years earlier, was completely solved. The production of such plates is, however, only of secondary importance.

* * *

In close connexion with these beginnings of the production of armour plates by F. A. Krupp, there is another great enterprise, by which, too, he advanced beyond the paths marked out by his father; this was the purchase of the Gruson works, which had long been engaged in the manufacture of armour for land fortification. The reasons which led to the combination of this enterprise with the Krupp firm will only become evident to the reader, when some preliminaries have been given of the origin and early history of the Gruson works.

Alfred Krupp's and Hermann Gruson's paths in life had crossed early though only casually. After Gruson had completed his studies in natural science at Berlin, which he combined with an apprendiceship as a volunteer at Borsig's engine works, he successfully occupied a series of important posts in the workshops of the Berlin-Hamburg railway, Wöhlert's works in Berlin, and lastly, with the Hamburg-Magdeburg Steamboat Co. at Magdeburg. This brought him frequently into contact with the Krupp Cast Steel Works, which was furnishing steel machine parts for these enterprises, so that he had an opportunity of appreciating the value of really good materials in machinery, especially when used as a means of traffic. He saw, too, that as far as good steel went, that produced in Germany was quite up to the required mark, but that in the manufacture of cast-iron machine elements, English industry was still far in advance of German. Though several German works could and did supply good chilled cast-iron rolls, though the manufacture of cast-iron railway wheels with hard tread had already been attempted, still on the whole, there was no uniform, pure, tenacious cast iron for machinery, which could safely be compared with the best English. Hermann Gruson took up this problem and devoted himself to it with the greatest assiduity. On June 1st 1855, when he was 34 years of age, he had, with his own capital, founded a small ship yard at Buckau on the Elbe, with engineering works and an iron foundry, and here he successfully directed all his energy to discovering what mixture of different sorts of pig iron would yield a pure cast iron of superior tenacity, which could be used for those parts of ships and machines hitherto made of wrought iron or steel. Besides this he tried to produce chilled-iron castings in the English and American way, *i. e.*, obtaining a hard surface by casting in chilling moulds. He was successful in both. At first he only employed this latter process for rolls, then he adopted it in a limited measure, for railway wheels, and gradually extended it to other objects requiring hardness combined with strength, for example, parts of crushing machines, mills, &c. Then in 1858, he had the happy idea of making chilled cast-iron frogs, crossings for railway lines, which had hitherto been made by joining iron or steel rails. He worked at this with all his might, and when almost at the same time the general depression of industrial life lay heavily on machine and ship building, it was this invention which brought Gruson considerable orders and saved his enterprise financially. The manufacture of durable cast-iron rail parts, of course, required castings not only of an unusually hard surface, but also of a very tough core, capable of withstanding shocks, and Gruson's researches succeeded, in a degree hitherto unequalled, in discovering how to combine mild iron of high tenacity, with a surface of extreme hardness. Thus, as early as the 'sixties, his factory possessed a well-earned reputation, not only for its unsurpassed chilled-iron castings, but also for the purity and excellence of the ordinary sand-mould castings used for machinery of all kinds. But it was the manufacture of chilled-iron shells for piercing armour plates, which he did not start till 1863, that laid the foundation of his universal fame, and led to the great development of his works. It was,—as was rightly said afterwards,—one of those bold leaps of an ingenious mind which we admire, without being able to grasp the course of thought which led to them. Professional men at first doubted the feasibility of this idea, but the result proved that Gruson was right. The glass-like hardness of his shells, combined with the toughness of their core, gave them a power of penetration far superior to that of unhardened steel shells, and this as well as their lower price, soon procured them a large sale. For some years chilled cast-iron shell was the predominating projectile used against armour plate.

Gruson drew the right conclusion from this success. In 1869, he removed his little factory to its present site—a much more spacious one. In his new, considerably enlarged workshops, among which the foundry was specially notable for its size and suitable appliances, he concentrated his attention on the perfecting of chilled-iron castings and their use in ever wider fields. The most important step in this direction was the taking up of armour manufacture from chilled cast iron. It was on the occasion of the firing of a rolled-iron Schumann armoured shelter in 1866, that Gruson resolved to try this use of it, and he at once proceeded to carry out his idea. He saw clearly that the flat plate form in general use for rolled iron armour, was not suitable to chilled iron. The curved form must contribute to making the striking projectile glance off the hard surface of the comparatively thick armour, and the bulk of the plate must suffice to absorb and diffuse the force of the impact without cracking. The firing tests made from 1869 till 1871 on a chilled-iron armoured shelter, made on these principles for a 21-cm gun, confirmed the suitability of the design. The knowledge gained here led to the construction of the chilled-iron armoured battery for coast defence, and after that of an armoured revolving turret, the cupola of which had the shape of a spherical segment and was composed of sectors placed side by side without being joined, the sectors reposing on a substructure of iron. Both in the armoured battery and in the turret, the gun tubes were laid in minimum embrasure carriages designed by Gruson to reduce the weakening effect of the loop hole on the turret to a minimum. An armoured ring serving as a glacis protected the substructure of the turret against fire attacking from below. Firing tests, which these chilled-iron armour successfully resisted, brought the factory in extensive orders for batteries and turrets armoured with chilled cast iron.

The increasing efficiency of siege guns and the curved fire for attacking fortifications, which continued to gain favour, also had their effect on the employment of chilled-iron armoured turret for inland fortifications. For the armoured cupola which rose above the parapet, was plainly visible and therefore an easy mark to hit, and still it was not adapted to resist a number of hits from level-firing guns, much less from curved-firing ones. Now in 1882, when a 15-cm armoured gun carriage was fired on the Kummersdorf proving ground, before the Artillery Experimental Committee, the brilliant success achieved by Schumann convinced Gruson, who was present, that this would be the design of the armour of the future. He joined Schumann without hesitation, in executing the latter's designs on a large scale, and thus included in the scope of his operations a new branch of manufacture of permanent importance both technically and commercially. Schumann caused the gun tube of his armoured mount, when it was elevated, to move between two guiding bars, which were fastened to the armoured cupola; it moved in an arc the centre of which lay in the middle of the loop hole. The armoured cupola of rolled ingot steel, with the gun tube and mount, is supported on a perpendicular column which revolves in a step bearing. The whole apparatus is sunk so deep in the ground that the rim of the flat cupola is level with the surface of the earth, and revolves in an armoured glacis. On firing, the shock of recoil of the gun which is rigidly joined to the cupola by its mount, is communicated to the glacis. The cupola is made to turn in a circle by the pivot and can also be raised and lowered a little. Gruson and Schumann succeeded by their combined efforts in developing from these simple principles all armoured constructions of the nature of armoured mounts, eclipsable armoured turrets, moveable mounts for guns and howitzers of various calibers, and—with certain modifications—also of mortars. The building of fortifications in modern times has been evolved from the adaptation of these Gruson-Schumann armour designs. Before this, at the end of the 'seventies, Gruson had acquired the sole right of making 3·7-cm Hotchkiss revolving guns in Germany. This was the beginning of his gun-tube production, which armour building soon compelled him to extend. His gun making was, however, limited to those of small calibers, from 4·7 to 8·2 centimeters for guns and 12 centimeters for howitzers for field artillery, further to 3·7-cm to 12-cm guns for armoured mounts, naval mounts and garrison carriages, and 12-cm to 21-cm ball mortars for armoured shelters. The gun and howitzer tubes were solid ones, for which Gruson got ingots from other iron works. The mortars were made of chilled iron. The middle spherical part, from which they take their name, effected the closing of the embrazure in the armoured cupola. The trunnions of the 12-cm field howitzers were at the breech end, a contrivance which was again adopted by Krupp a few years later also. The Gruson vertical breech-block of 1887 led to designing of quick-firing field guns for the use of metal cartridge cases. This breech-loading mechanism was used for all other guns in armoured and naval mounts, they were thence called quick-firing guns. The field guns were at first of 4·7 centimeter, 5·3 centimeter and 5·7 centimeter calibers, they were tried in several foreign states between 1889 and 1891. By 1890 field guns of 7·5 to 8·2 centimeters were added, the tubes of the latter had bronze jackets over steel inner tubes. The testings, necessitated by the extension in gun manufacture, led to the laying out of a proving ground at Tangerhütte in 1888. This ground—8·5 kilometers long by 2 kilometers wide,—is still used by the Cast Steel Works.

When Gruson took up the making of chilled cast-iron shells, he came into touch with Krupp, as a manufacturer of war material. The connexion thus begun, strengthened, when at the beginning of the war of 1870, Gruson undertook the making of some 21-cm coast-defence mounts for which Krupp supplied the tubes. Though in the rivalry which originated thus, Krupp's steel shell and coast-defence mounts carried the day, still Gruson attained lasting success both with his chilled cast-iron armour and with the Schumann armour designs. But he had to depend partly on other steel factories for his ingots, and for finished tubes of 15 centimeter caliber and upwards on Krupp entirely. And when the adoption of Schumann's designs led to the employment of ingot steel instead of chilled cast iron, for cupolas, Gruson had to get that from other works too. These limitations, however, did not prevent his advancing in the manufacture of quick-firing field and naval guns of his own design, and of entering into keen competition with Krupp both at home and abroad, at the end of the 'eighties. At that time the armour-plate rolling mill was being built at the Cast Steel Works, a further union of Krupp's and Gruson's common interests, so that each was often able to supplement the other's work. These circumstances gradually matured the conviction on both sides that a combine would be for the advantage of both parties, and would raise the prestige of German industry abroad Krupp's well-established reputation made it absolutely necessary, now that he had begun the manufacture of armour, that he should take a leading position in this field too; it would have been a wasteful and detrimental frittering of resources, if a second enterprise had been begun at a great expense. This was F. A. Krupp's view of the matter and he expressed it in these words:—"The manufacture of armoured turrets was an absolute necessity for my works, but I know that the world's market cannot employ two German firms in this field. I should have rendered ill service to my country, if I had paralysed a prosperous German industrial work by dint of superior capital, therefore I preferred to purchase the Gruson works, and I hope that the results of this decision will be increased prosperity, for them and for me." In 1892 a contract of lease was drawn up and signed between the Gruson works—which had been transformed into a limited company in 1886—and the Krupp firm. In May 1893, the Gruson works were taken over by purchase, as the firm of "Fried. Krupp Grusonwerk". Hermann Gruson himself had already retired from the actual management of his factory by entering the Board of Trustees, and he took no further part in its development. He died in 1895.

Thus the Gruson works became part of the large sphere of action of the firm Fried. Krupp, a part nearly akin in certain details, yet independent on the whole. Since its transformation into a limited company it had almost doubled its property, the number it employed and its turnover, while the premises had been considerably extended; in 1893 the number of hands amounted to about 2800, the extent of workshops and other buildings to 7 hectares. The preponderating part of the turnover came from orders for war material, although the production of chilled cast iron for civil industries, of machines and machine parts, as well as entire industrial plants, represented a value of some millions. At present, this proportion has been reversed, owing to the thorough-going division of work between the two factories. More than three-quarters of the greatly increased output of the Grusonwerk serve peaceful ends. The making of guns and projectiles has been entirely transferred to Essen, and the shops of the Grusonwerk for those branches are considered as auxiliaries. On the other hand, the production of coast-defence and garrison armour, is for the present still left at the Grusonwerk.—There were old points of contact too, between the two works in the domain of civil industry. The Gruson chilled cast-iron rolls which had quickly gained world-wide fame for their unsurpassed hardness, tenacity, and purity of surface, were not only used as large rolls in the paper, textile, metal and rubber industries, for mills and all sorts of crushing machinery, but also for various purposes in smaller works, where they came into competition with Krupp cast-steel rolls; for instance, as gold and other precious metal rolls, wire rolls, for doublé, foil, lead and steel plates and other things. Many thousands of chilled cast-iron rolls are produced every year at the Gruson works, from the lightest weight to the heaviest, from small rolls for mints, to gigantic ones of 40,000 kilogrammes and upwards.—The manufacture of small rolling mills, which used to be an important feature of the Cast Steel Works, has been handed over entirely to the Gruson works, and in cases where cast-steel rolls are required they are supplied by the Essen works. The Gruson fluted and toothed rolls, and other chilled cast-iron rolls with surfaces adapted for crushing mills and breaking machinery are very generally used. At first only the cast-iron working elements were supplied, but the building of the entire machines very rapidly developed from this beginning. Just as Krupp was led by the production of steel to the manufacture of finished articles of the most varied kinds, so the natural result of the constant employment of chilled cast iron for the working portions of crushing and rolling machinery, was the building of the machines themselves, so as to create certain types of machines and to secure the best possible utilisation of the chilled cast-iron elements used in them. The well-known Excelsior mills for kibbling corn, which have been used by numerous firms in every part of the known world, for the last 20 or 30 years, the Gruson ball mills for crushing the hardest materials, which worked a positive revolution in the technic of crushing, and the stonebreaking machines with chilled cast-iron cheeks are among the oldest articles of this description. Later on edge runner mills, stamp batteries, beater and centrifugal mills and a long list of special machines for the most varied purposes were added, so that Gruson machinery still plays an important part in the technic of crushing apparatus. Articles of this kind less well known, though they have been very widely used, especially in other continents, may be mentioned:—sugar cane mills, with complete plants for the making of cane sugar, fibre extracting and shelling machines for working up palms, agaves and other fibrous plants, coffee preparing machinery, pulpers, separators and polishing machines, cotton presses, oil presses and entire plant for the manufacture of oil. However, at present as formerly, the making of cast-iron articles, alongside of machine construction, forms an essential part of the output. The Gruson works are famous throughout the world for articles of extraordinary size, weight and durability, *e. g.* cylinders for hydraulic presses, big cast-iron tanks or vessels, big shells for road rollers, heavy rolls for crushing sugar cane, objects which sometimes weigh as much as 100 tons. The finishing of such castings made the creation of unusually big and heavy machine tools necessary; the roll-turning shop, with its peculiar tools adapted for the finishing of chilled-iron castings, the erection shop with its travelling cranes for the fitting of the heaviest rolling mills are among the most interesting parts of the works. Railways offered a very considerable market, especially formerly, and the factory soon went beyond its original products in this department, such as frogs, points, switches and wheels, and began the manufacture of entire sets of wheels.

After the Gruson works had taken up the building of machines, they was naturally driven to the manufacture of complete machine plants for the kinds of shops in question, so as to facilitate the sale of these products. This measure has, especially in the last few years, helped both to widen the market and to enlarge the premises. First the production of plant for crushing purposes, which plays so large a part in industry, was developed.

The Gruson works build these plants for every possible purpose, whether for stones, fruit, fibres, or any other material. They were the first to undertake, and with great success, the erection of entire cement works, and at present hold the front rank among the works which are engaged in such building, especially since they began the manufacture of revolving calcining furnaces, which, as is well known, are among the latest improvements in this field. The factory has an experimental department of its own, in which the most suitable processes for crushing any material sent in, is settled, and where new crushing machines are also tested. At the same time, minute observations are made as to the output, durability, and efficiency of all new machines. Another speciality, which has gradually been evolved in the manufacture of crushing machinery, and which has now attained great importance, is the technic of dressing. Numerous appliances, especially for dressing gold, silver, copper, zinc and other ores, have been sent out of the Gruson works for home mines and metallurgical works, and also for foreign ones, some in America, and this branch of manufacture is still on the increase. A large testing department in the works selects the most suitable treatment and machinery for dressing each specimen of ore sent in, the necessary chemical analyses are made in a laboratory, finally the process best adapted to the different kinds of ores used in entire smelting works, of the most varied branches, can be determined by experiment, *e. g.* for lead and tin works and the like. So such works, especially those abroad, can save themselves the making of these difficult, costly and often uncertain experiments. The manufacture of electro-magnetic separators with a dry or wet process has also been taken up with special success.

The Gruson works have greatly increased their former size and importance since they have passed into the hands of Fried. Krupp. The number employed, which amounted to 2800 in 1892/93, has risen to 4560 in 1910/11, the area of the premises from 13 hectares to 44, and the area built over, from 7 to 11·4 hectares. This development has been attended by a corresponding increase of output, which is now three times as much as it was when the works were taken over. It is also worthy of remark that the Magdeburg works do a large average of business for the foreign market. Until the beginning of the nineties, the greater part of the war material from the Gruson works found its way abroad, while most of the peace material went to the home market. But since it has begun to build machinery and plant for abroad, the civil products of the Magdeburg works have found their way into every part of the known world, so that now half the total output, on an average,—in some years even more—goes out of the country.

But the change of ownership was not important for the Gruson works alone; it was also a step which carried the Cast Steel Works considerably beyond the scope of its original activity and could not fail to influence its further development. It was in such decisions as this, that F. A. Krupp showed how fully equal he was to his task. He was as determined as his father had been to stand in the first rank of steel producers at any cost; and to keep the lead among the makers of offensive and defensive weapons. It was these motives which also led Krupp to take over the Germania shipyard a few years after the purchase of the Magdeburg works.

* * *

Since the advance of the German steel industry through the adoption of the Thomas process, the business done between the German iron industry and German shipyards had gradually become more varied and more regular. German shipbuilding was freed from its dependence on the English iron and steel market, first in building warships, owing to the encouragement given to home trade by the German Navy, and soon after in the merchant service. The German steel and rolling works, the steel foundries and engineering works were urged on by foreign competition, and showed themselves worthy of confidence. The ship plates produced in German rolling mills advanced from 17,000 tons in 1880 to 210,000 tons in 1901, German industrial works, especially the Bochum company and Krupp, gained a high reputation for steel castings in the international market, and the German armour-plate works trod closely on the heels of the English. For decades the Krupp firm had been very closely and constantly connected with shipbuilding. The manufacture of naval guns and mounts, of armour, of the heaviest shafts and crank shafts, which had been carried on for many years, the production of big steel castings and lastly, since 1879, the making of iron and steel plates for shipbuilding, were all old and important branches in the Cast Steel Works, and Krupp's manufacture enjoyed a very high reputation even with foreign shipbuilders. Still it was not possible to diffuse these products as widely as they deserved, so long as Krupp was limited to employing his armour, his guns, his steel castings, &c. for ships built in yards belonging to other owners, while English firms like Vickers and Armstrong had long been able to build not only trading steamers, but also complete fighting ships in their own yards. These were very urgent reasons why Krupp should undertake shipbuilding. By the great amount of pig iron it produced, and still more by the resolve made at the beginning of the 'nineties to adopt the Thomas process in iron works of great extent, the Krupp firm was in a position to furnish from its own shops all that is necessary for shipbuilding, from the making of plates and sections to the equipment of a man of war. It was obvious that this fact should be taken advantage of, and that the firm should include shipbuilding in its programme, and this could best be realised by the purchase of some large shipyard. The unique position held by the Cast Steel Works in gun and mount manufacture made the building of fighting ships the chief object of consideration, and it was F. A. Krupp's express wish that the shipyard to be bought should be in a German naval port. Thus the attention of the firm was drawn to the Germaniawerft, which answered to these requirements by its situation on the Bay of Kiel, and at the same time met Krupp's wishes, as it was connected with well known workshops for building marine engines.

The previous history of the Germaniawerft reaches back to the middle of the nineteenth century. A small yard founded in 1863, by the shipbuilder Bruhn of Bornhöved, on a Danish concession, was the beginning of the enterprise which subsequently became so great. In a short time Bruhn's yard passed into the hands of the English industrialist Lloyd Foster, who with the help of English and German capital intended to turn it into the "Norddeutsche Schiffbaugesellschaft", for the construction of ironclads and other ships of war. Nothwithstanding the willingness of the German Admiralty, to place its orders for battleships with this enterprise, it never attained the intended proportions, and in 1867 it was reestablished with the assistance of the town of Kiel under the name "Norddeutsche Schiffbau-Aktiengesellschaft" at Gaarden, with a nominal capital of one million Talers, it was now designed for the erecting and working of establishments in Kiel harbour, for building and repairing all kinds of iron and wooden battle and trading ships, of dry and other docks, and also for purchasing and establishing places suitable for getting and producing the materials and machinery required in shipbuilding. Hermann Gruson was a member of the board of trustees, and among the managers there were some well known names:—for instance Georg Howaldt, who afterwards founded the Howaldt shipyard, and Schlick, the inventor of the gyroscope. The new enterprise worked very briskly for the first few years, among other ships built here were the corvettes with decked battery 'Bismarck' and 'Blücher', and the emperor's first yacht the 'Hohenzollern'. The two first Krupp steamers for ore transport, the 'Essen' and the 'Sayn', were also built at the yard of the North-German shipbuilding company in 1874, their building numbers were 53 and 54. But the enterprise suffered severely during the general depression of trade in the 'seventies, and was at last put into liquidation in 1879. Ultimately it was bought by the "Märkisch-Schlesische Maschinenbau- und Hütten-Aktiengesellschaft", which had sprung from the well-known Egell's engineering works in Berlin, the creation of a Westphalian machine builder. In 1822, Egells had set up a little foundry and works for building stationary engines, with ten workmen, then from the 'thirties onwards he had been the first ironmaster to take up the building of marine engines, and so had brought his factory to a brilliant position. As orders increased the workshops were moved from Berlin to Tegel, and very much enlarged, then the Eintracht works in Silesia with several ore concessions were bought and at last the whole enterprise was transformed into a limited company, under the management of August Minssen, who afterwards was an active and successful member of the Procura of the Krupp firm. While Egells was still at the head of the works they had made the first engines for the Imperial German Navy; after their enlargement and their transformation into the Märkisch-Schlesisch company, they were occupied to a very great extent with the manufacture of auxiliary engines for German battleships. This enterprise had therefore much the same reasons as those that moved Krupp later on, to incorporate an efficient shipyard with its already fine works for engine and boiler building. The step led, however, to no favourable results for the Märkisch-Schlesisch company. In the endeavour to make as much use as possible of their establishments in Berlin and at Kiel, the company undertook to build a number of ships at unremunerative rates, and this, combined with the unfavourable state of the shipbuilding industry at the beginning of the 'eighties, placed the combined enterprise in difficulties once more. In 1882, the two branches in Berlin and at Kiel, after getting rid of part of their property, were fused into one establishment styled the "Ship & Engine Building Company Germania", so that their continued existence was assured. In technical respects the works had never gone down, and in the first annual report of the new company, mention could be made of a 2700-horse power engine built for the German despatch boat the ,Blitz', which reached a speed of 16½ knots on the trial trips, and thus had made the 'Blitz' the quickest boat in the German Fleet. The 'Blitz' had been the first building number after the transfer of the yard to the Märkisch-Schlesisch company. A long list of fighting ships and trading vessels have been launched in the years 1882 to 1896 at the Germania shipyard, we will only mention the armoured ships the 'Wörth' and the 'Siegfried', the cruiser corvette the 'Kaiserin Augusta', the torpedo boat 'G 21', which on its first trial trip in 1885, reached the highest speed—18 knots—ever attained so far by a torpedo boat on its trial trip. The excellent engines of the Germania company, which were still built in the Tegel works, were always highly esteemed. For instance, the company received a premium of 300,000 Marks for the extra efficiency of the engines of the 'Wörth'. A considerable number of torpedo boats, for which the yard soon became very famous, were also built for abroad, besides a number of trading vessels for home and foreign ship owners. But the financial results did not keep pace with the technical successes. The want of capital, which existed from the first, prevented the enlargement of the works at the right time, and the great distance at which the engine-building branch lay from the ship building proved more and more detrimental, as the machinery required became heavier and more powerful.

Under these circumstances the Krupp firm's decision to take over the Germania shipyard—first by working it by right of pre-emption—and to enlarge it at their own expense according to modern requirements, meant the beginning of a new era for the Kiel enterprise, while the Cast Steel Works assumed a heavy technical and financial strain for some years, by undertaking buildings which required such great labour and outlay. The working was taken over on October 1st 1896, the preparations for re-constructing the yard were begun forthwith, and the work was fully completed between 1898 and 1902. The alterations made resulted in a totally new creation, for the mechanical workshops were moved to Kiel, a great deal of land was bought, and some building land was exchanged with the neighbouring property of the Imperial shipyard. The area of the yard was increased from 6 hectares to 22·5 hectares, the area built over rose from 1·3 to 9·4 hectares; the water frontage, which was formerly 400 meters long, was doubled in length. By the exchange of property with the Imperial yard the premises of the Germaniawerft have certainly been pushed further into the inmost bend of the bay of Kiel, still the water there is deep enough to allow of a channel about 10 meters in depth, being kept open for the biggest sea-going vessels, and the climatic condition of the bay permits the launching of big ships and the making of trial trips even in winter. On the other hand the low level of the land and its partially boggy substratum, necessitated a great deal of dredging and depositing of earth: part of the ground by the water—the "Unterhof"—had to be raised 1½ meter to 3 meters, for which the earth removed from the "Oberhof", lying inland, could be utilised. One and a half million cubic meters of earth had to be shifted. On the newly formed ground, which with its solid sea wall rises about 5 meters above the water level, seven big slips were built, reckoned for ships up to 250 meters long and 34 meters wide. The first four of these stand under glass sheds. An eigth slip is reckoned for ships 250 meters long and 40 meters broad. The roofing over of the older slips with glass and iron constructions was done, firstly, so that work could proceed uninterruptedly in bad weather and in winter, and that both men and unfinished ships might be protected from the severity of the weather. The size of ships has increased so greatly of late years that the length and breadth of these slips was soon insufficient for the larger ones, new covered slips therefore have not been built after that. The four roofed slips, with their high walls of iron and glass, combine with the enormous wharf and floating cranes to form a peculiar feature of the yard which is visible from a great distance. Besides the seven large slips, there is another broad open one of a different form, on which several small vessels—torpedo boats for example—can be built simultaneously, or buildings of unusual dimensions, such as floating docks, pontoons, &c. be put on.

When the slips and workshops were rebuilt, the strictest attention was paid to providing against unnecessary transport to and fro, and to arranging all so that every piece should travel in the shortest line through the different shops where it was worked, from the place where it entered the yard, to that where it was built into the ship. Therefore the iron foundry, the boilermakers' shop, the electric power station, and some other auxiliary shops were placed further away from the water. Beside the place where the railway enters the yard is the plate storage, this storage yard is commanded by an one-legged gantry crane with a radius of 60 meters. Near the storage are the galvanising shop, the plate-pickling plant where the plates are cleaned from oxides, and the heating furnaces, which can take pieces 18 meters long. From there, the plates and other building materials are taken into the plate forge, the frame-bending shop, and so on, until they are finished and brought into the big ship-building hall which lies all along the landward side of the slips, and forms the connexion between the actual building places and the preparatory shops; the hall is 160 meters long by 45 meters broad. A great number of cranes of every kind, mostly driven by electric power, facilitate transport in and between the workshops, and the combining of the parts on the slips. By the side of the slips and the ship-building hall stands the largest group of shops which work in connexion, the erecting hall, which consists of seven large bays, covering an area of 21,000 square meters. In this, marine engines are made in detail, fitted up, and submitted to the prescribed tests of efficiency. The building of stationary steam engines which used to be the principal business of the works at Tegel has also been continued at Kiel, but piston engines, of which so many were formerly built at the Germaniawerft, have given place to turbines, which have lately come into use for all descriptions of war vessels and even for merchant ships. During the last few years, besides turbines, crude-oil motors have been built. This branch which was begun in 1906, and to which great attention is being given, is rapidly gaining ground. The Germaniawerft builds these motors on the Diesel system, in which patent it is a co-partner, not only for small craft and stationary plant, but also lately for large ships. For instance, in 1911, three crude-oil motors were building at the Germaniawerft, for three petroleum tank steamers ordered there, of upwards of 30,000 tons burden and a total output of 8100 horse powers. In this shop the enormous finishing machine tools for the steam turbines of the latest warships call for special attention. In the making of these turbines the toughest and hardest materials must be combined with mathematical precision of work. By the end of the year 1911, 26 marine turbines, with a total efficiency of 300,000 horse powers and 129 stationary turbines with a total of 153,000 horse powers had either been finished or were making. In motor building too, the machines for stationary plant outnumber those for propelling ships, while the latter exceed the former in power.

In the erecting hall, as in the whole yard, the separate departments are so grouped, that raw materials and half finished pieces can be brought to the erecting bay by the shortest way possible. Therefore all the auxiliary mechanical shops, the turning shop, the plate-finishing hall, the copper forge, smithies, &c. have been placed in the immediate neighbourhood of the erecting bay, and in front of it rises the huge wharf crane—which hauls up to 150 tons, but has been tested for 200 tons—by means of which the finished engines are placed in the hull of the ship. There are other cranes of very great hauling capacity in the armour-plate storage, and the fitting shop, where the prepared plates get their final touches. For conveying the heaviest weights to ships which cannot be brought immediately in front of the big wharf crane, there is a gigantic floating crane, 75 meters high when quite upright, and of a hauling capacity of 150 tons. This is at the present time considered one of the most perfect hauling appliances in the world. Eastwards from the lower yard lies the spacious upper yard, which can be still further enlarged by the removal of more earth; here are the independent groups of workshops, the boiler-makers' shop and the iron foundry. In the boilermakers' shop, which has an area of 10,000 square meters, the chief work is the making of boilers, on the well-tested system according to the former yard director Schulz : a tube-boiler system, which excels for safety in working, quick evaporative efficiency and excellent utilisation of the heating gases, and which, after extensive tests, has been adopted by the German Navy as their normal boiler. Of course, boilers of other designs are also built. Quite near the boilermakers' shop stand the electric works, the power station for the whole yard, with an output of 3000 horse powers, here also the engines are placed for driving the compressed air plant. In the iron and metal foundry, which covers an area of 14,000 square meters, the greatest part of the castings used by the Germaniawerft are produced.

Thus at the newly erected Germaniawerft the Krupp firm has set up an establishment, which is at least equal in efficiency to the other big private German shipyards. A considerably increased activity followed the efforts that had been made. The number of workmen, which during the last few years before Krupp took over the works, had been 1300 or so, rose in the following years to more than 3000, and at presents amounts to about 4500. The present extent of the yard, however, would suffice for 7500 hands. There is a workmen's colony of 215 dwellings of from three to five rooms, for the accomodation of married workmen, a lodging and eating house for the unmarried. There are 36 dwellings for the staff in Kiel and Gaarden. Work at the yard has been brisk, both during the building and since its completion. Since the Germaniawerft came into Krupp's possession, it has taken the highest place among German private shipyards in the building of war vessels. From 1896 till December 1911, the Imperial Navy gave orders for 9 battleships, 5 small cruisers, 33 torpedo boats and 10 submersibles. The yard has also received foreign orders for the navies of Austria-Hungary, Norway, Russia, Brazil, Argentina, Italy, China and Turkey. The Germaniawerft has taken the lead in Germany in submarine boats, it is the only German private yard that has built any. In 1902, a submarine of 17 tons displacement was built as an experiment, the proving of which gave such good results, that the Russian government purchased it, and at the same time gave an order for three larger boats of the same type. The Germaniawerft received the first German order for a submersible boat in 1905; afterwards orders for nine more were given. The Germaniawerft has also made submersibles for Austria-Hungary, Norway, and Italy. The yard has also made a name by its success in building racing yachts, several of which it has supplied to the Emperor. In 1908 the schooner yacht 'Germania' was built at the yard for Mr. Krupp von Bohlen und Halbach. The 'Germania' took part in the Kiel regatta week and in several other races, with so much success that the English sporting papers acknowledged this purely German production to be the best yacht that has ever sailed in British waters. In consequence the German Emperor entrusted the yard with the building of his new yacht, the 'Meteor'. In building trading vessels the Germaniawerft has not been so active as in the lines above mentioned; of the last named kind, only 14 have been built there since the Krupp firm took it over. The largest of these is the 'Kronprinzessin Cäcilie' of 19,000 tons, a freight and passenger steamer, belonging to the Hamburg-America line.

## SOCIAL BETTERMENT INSTITUTIONS.

After the erection of workmen's dwellings on an extensive scale in the 'seventies, a commercial crisis put a stop for some time to the development of measures for the welfare of the employees and men. A fresh impulse to the movement was given, however, by Friedrich Alfred Krupp, whose philanthropic nature found real pleasure in such work. Most of the measures taken subsequently originated with him. The prosperous state of the works, which now advanced with giant strides, enabled him to follow his bent in this direction, and to carry out the programme of the General Rules and Regulations, while he widened the objects of his care for his workpeople, which his father had been obliged to confine to the strictly necessary. First he enlarged the circle of those benefited, by including in it the staff, as well as the workpeople. His efforts were mainly directed to the promotion of instruction and culture, recreation and games and entertainments of various kinds; a long series of institutions with these aims originated between 1887 and 1902. He also made new institutions for the encouragement of thrift. He devoted his attention, however, equally to the extension of those already existing, such as:—the Pension Fund, the Supply Stores, the providing of dwellings, which he developed according to the needs of the rapidly growing factory.

Friedrich Alfred Krupp took the first step in this field immediately after his father's death, by founding the "Workmen's Endowment". This endowment to which a capital of 1,000,000 Marks was allotted, is, in accordance with the wishes of the founder, exclusively for the benefit of the workmen in the factory and their wives and children; all employment of the funds for objects prescribed by law is strictly excluded. The interest proceeding from the endowment is, in the first place, applied to relieve cases of need among the men, which have arisen without any fault of their own, and then for the widows and orphans of those who have died before reaching the age which entitles them to a pension; next to cases of long illness, when the aid given by the sick fund ceases or is insufficient. The money of the endowment may also be employed to erect institutions for the corporal and mental good of the workmen or to support existing institutions of such kinds. The control of the income derived from the endowment, and the decision as to how it shall be used, is entrusted to a managing body, composed of workmen and members of the staff. The importance of this endowment consists in its being the first measure taken to carry the provisions for the welfare of the men beyond their original limits, by completing the legally enforced insurance of workmen and the pension fund already existing in the factory. The "Aged Workmen's Endowment" which F. A. Krupp established in 1897—also with a capital of a million Marks—on the occasion of the centenary of the Emperor William I's birth, has similar objects. This endowment is intended to meet the needs of disabled workmen, when the provision made by the State for the workmen and his family requires supplementary aid, not already provided by the Pension and Relief Funds existing in the Krupp works. The moneys of this endowment are also, in the first place, to be employed for the support of men unable to work. The managing body of the Workmen's Endowment has the charge of this also. These endowments have in the course of time been considerably increased in value, by large donations from the owners of the firm, so that on January 1st 1912, they possessed a capital of upwards of 8½ million Marks and could dispose of an income of over 325,000 Marks for the current year.

Nextly Friedrich Alfred Krupp made most generous provisions for his officials. In 1890 the "Officials' Pension Fund" including their widows and orphans, with a capital of 500,000 Marks was established, and every employee receiving a salary of upwards of 2000 Marks had to become a member of it. This fund is so connected with the Workmen's Pension Fund, that when members of the latter pass with increasing age into the list of the Officials' Pension Fund, they enter with only the amount of their income which exceeds 2000 Marks. When an employee joins the fund, he has to pay a sum equal to a month's salary, further 3 per cent of the yearly appointments as regular contribution. A sum equal to this is given by the firm which besides has, from time to time, made donations amounting to 4,650,000 Marks. Five years' service constitutes the right to a pension. The pension is only paid on the first 10,000 Marks of salaries which exceed that sum. The pension amounts to fifteen-sixtieths of the salary when the time is reached at which it may be claimed, and it rises by one-sixtieth annually till 35 years service are completed. Thus the maximum pension after a 35 years' service, for an income of 10,000 Marks, amounts to

7500 Marks; the minimum after 5 years' service and a salary of 2000 Marks to 500 Marks. Widows and orphans are likewise entitled to a pension; that of the widow amounts to one half of her husband's, that of orphans under 18 years of age to one-twentieth of the father's. According to the balance made on June 30th 1911, the Officials' Pension Fund possessed 4120 members. The property of the fund amounted to a round sum of 11,000,000 Marks. The amount of the pensions paid in 1910/11 was 473,000 Marks, widows had received 214,300 Marks, children 11,950 Marks, temporary aid had been given to the amount of 3250 Marks, making a total of 703,000 Marks. Since its foundation the fund has paid out altogether $6^1/_4$ million Marks.

Besides this fund, insurance against accidents was instituted at the same time for those employees who did not come within the limits of State insurance. The annuities granted in cases of total disablement by an accident occurring in the works, amounts to two-thirds of the salary; if death is caused by the accident the widow gets 20 per cent and each child 15 per cent till the age of 18, the family altogether a maximum of 60 per cent. In distinction from the regulations of the Officials' Pension Fund, the compensation given in cases of accident is based on the total yearly salary; of course payments are deducted which are due from Pension Funds to which the firm contributes, but no deductions are made for amounts due from Life Insurance or Accident Funds. The amount of the annuity is fixed by employees of the firm, and appeals are heard by a board of arbitration.

Under the head of attempts to encourage thrift we must place the institution of a Savings Office in 1900 with its regulations, which were made at the same time. These were not the first steps the firm had taken in this direction. Those employed at the works already had obtained the right to invest savings in lump sums of at least 200 Marks in the Cast Steel Works, at the rate of 5 per cent interest. At the present time 6000 persons avail themselves of this arrangement and thirty million Marks have been deposited in this way. The Supply Stores had also undertaken to effect deposits in the Town Savings' Bank, and to sell Savings' Book-stamps. The Life Assurance Association has been mentioned before. Now F. A. Krupp wished to combine these institutions into a system. A special office at the Cast Steel Works to act as a medium between those employed there and the Public Savings' Institution was erected. At the same time a special kind of Savings' Bank was introduced, with the object of facilitating thrift as much as possible, by conveniences for saving, and to reward perseverance and regularity in thrift. This is effected as follows:—the Savings' Bank is connected with the payment of wages and salaries, so that regular savings amounting from 1 to 20 Marks per fortnight can by request be kept back when the wages are paid. Participation in this is quite voluntary, and no one is under any permanent obligation for any specified length of time if he participates. The amount so deducted may be raised or lowered at any time, according to the limits fixed, or they may be discontinued. Deposits to the amount of 300 Marks are returned on demand, for sums exceeding this amount three months' notice is prescribed but has not yet been insisted on. The employees of the Savings' Department are bound to the strictest secrecy. The savings are deposited in the Essen Savings' Bank. The advantages accruing to the depositors consist in the fact, that the firm adds to the interest the sum required to make a total of 5 per cent, and that a further premium of 1 per cent on the collective deposits is given in the form of an annual lottery, according to the amount standing to the credit of the concern. For every 100 Marks deposited the depositor gets a ticket, a ticket is also given to a minimum of 25 Marks. Out of the funds at the disposal of the lottery, first one premium of 500 Marks is set aside, then one of 300 Marks, one of 100 Marks, and the remainder is divided into premiums of 50 Marks.

The intention of the Savings Department is thus described in a booklet issued by the Savings Office:—"By this institution an opportunity is offered to the workmen and employees of investing sums as small as 1 Mark at 5 per cent, and besides of receiving a share in the lottery which takes place annually. Those who join the institution are thus enabled to become, in the easiest manner, possessors of a deposit which they can withdraw at any moment, and which would be a help to them at times when unforeseen expenses or needs make extra claims on their purses. To save of one's own free will—when that is possible—before misfortunes occur, to draw interest and premiums and to maintain one's independence of outside help, is obviously better than to be compelled to borrow and pay back sums, possibly with interest." The Savings' Office soon outlived the initial difficulties and the mistrust with which it was at first regarded, and now enjoys the unmixed approval of the employed. On the 1st of January 1912, there were 17,182 depositors—that is to say 47 per cent of the workmen and 70 per cent of the subordinate employees who are allowed to join, with an invested capital of 6½ million Marks. In 1910/11 the firm granted 115,600 Marks for interest and premiums. This institution, after its success had been proved in the Cast Steel Works, has been during the last years extended to the outlying works. The number of depositors in these amounts to 4775, the amount deposited exceeds a million Marks.

The further extension of provision for dwellings began at the end of the 'eighties, with an interesting experiment to render the acquisition of a house possible for a certain number of the workmen, or to facilitate it by granting loans. Half a million Marks was placed at the disposal of the Home Purchase Loan with the condition that the money lent should be paid off by instalments to a sinking fund, and that the amount thus paid back should be further lent out. The results of this arrangement did not give general satisfaction. While in rural districts surrounding the outlying works, especially in the iron-ore mining districts the institution proved satisfactory, and is still carried out successfully, the experiment was more or less a failure in Essen. The rapid growth of the town, and the high and increasing price of land, the demands made by police regulations, and the great expense of laying the streets, converted the aim attempted—the permanent possession of a small house for one family—into its exact opposite. In many cases large houses were built, which became the prey of speculators when the mortgage was paid off. As the firm could not possibly take over houses which were scattered about over the whole of the large town, there could be no question of asserting the right to purchase. Therefore the plan was given up as far as regards Essen. Loans to Tenant Co-partnership Societies proved a better means of promoting the building of workmen's dwellings in the town without the firm's occupying itself with the matter, and such societies were assisted both in Essen and in Magdeburg with considerable sums.

The safest way, however, to the betterment of housing the workmen still lay in the building of dwellings by the firm itself, so this was begun again in 1890, after an interval of nearly 15 years, and has continued ever since without interruption. The number of the firm's dwellings had risen from 3400 in 1887 to 4300 in 1902, although 500 old dwellings had been pulled down during that time, to make room for extensions in the works. It was not only the workmen who were benefited by this, but dwellings were provided for a great number of foremen and employees. First the colonies of Baumhof and Cronenberg were extended as far as building ground allowed. Then in 1894, the colony of 'Alfredshof' was begun at a somewhat greater distance from the works. Here in the open country, the system of detached houses could be carried out, in which 2, 3 or 4 dwellings were provided under one roof, each dwelling, however, was separate and self-contained, and provided with its own garden and entrance. This system, which the space required and the great attendant outlay rendered rather costly, was partially abandoned later on, and when the completion of the Alfredshof was finally undertaken, after a longish interval occasioned by the disturbances of the ground arising from the underlying mines, the growth of the town had so surrounded it on all sides with large houses that, on aesthetic grounds alone, it was necessary to complete the colony with higher houses divided into flats. The experience gathered here goes to prove that the question as to whether detached houses or blocks divided into flats are better, cannot be settled theoretically to meet all cases, and that the latter are more adapted to large towns under the building conditions which now prevail. In 1899 the building of the colony 'Friedrichshof' was started on the south side of the town. The large blocks divided into flats already existing there, and the limit of the space at the firm's disposal decided the matter, and, from the first, large three-storied blocks were planned. The distribution of the buildings is, however, spacious; they are grouped round large courtyards planted with trees and shrubs. We must also mention the dwellings provided at the outlying works. Of these there were in 1902, 1307 as compared with 531 in 1887. Where circumstances permitted small detached and semi-detached houses were built.

The celebrated 'Altenhof' owes its existence to a special endowment. At the unveiling of the monument erected to his father by those employed at the works, F. A. Krupp expressed his intention of carrying out a project which his father had long mediated, and which had occupied his mind during the last days of his life. "A happy home shall be provided where old disabled workmen may spend their last years, by the erection of small houses with gardens in a pretty and healthy situation, houses where they can live rent free for the rest of their lives." For the execution of this plan a farm was chosen on the south side of the town, near what is now the town wood, and more land was purchased afterwards. It was decided first to build 100 dwellings, "to be bestowed on the worthiest and the neediest old workmen, by a committee consisting partly of workmen". The Altenhof had a special charm for F. A. Krupp; he enlarged it several times, and had two little churches built in it, where divine service is held regularly; then a number of houses for widows were added, some houses for widows and widowers, and lastly a basket-making shop, where the old pensioners who still yearn after work can find light occupation. At present there are about 450 dwellings at the Altenhof, there is abundant space for further extension, and it is intended to build from 30 to 40 new dwellings every year. There is also a large well-kept park adjoining the Altenhof and belonging to it, to which the public are admitted as well as the pensioners. The 'Kaiserin Auguste Victoria Convalescent Home' is a special feature of the Altenhof, it was built by F. A. Krupp in 1896/97, and endowed with 300,000 Marks to lighten the cost of admission to it. Its aim is to provide a place where members of the Sick Relief Fund who need rest and change of air, can spend some time in the country and be well taken care of. The house is prettily situated close to the wood, it is surrounded by a large park-like garden, which slopes to the south. It has been considerably enlarged since its erection. The medical superintendence is in the hands of the staff of doctors attached to the Krupp hospital.

There are marked differences between the buildings erected before and those erected after 1887. Very clear rules and principles were evolved in the endeavours made for constant progress and betterment in the dwellings of the employed. First of all, the standard was raised in the quality of the buildings. This included an increase in the size of the rooms, and whereas formerly a room had an average area of 15 square meters, the average was now fixed at 16 to 17. Nextly the space allotted to the accessory offices was raised from 10 to 18 square meters, so that the self-contained dwelling could be much better fitted up. The rooms were also better arranged in regard to light and ventilation. Then systematic endeavours were made to prevent overcrowding in the smaller dwellings. In his desire to help the very poor, Alfred Krupp had built half his dwellings with only two rooms. Now three- and four-roomed dwellings were built, and some of the two-roomed dwellings were joined so as to form three- or four-roomed ones. So that in 1902, the two-roomed dwellings formed only 39·6 per cent of the whole number. The number of occupants was reduced from 5 to 4·36 per dwelling. Since then further measures have been carried out, and at present there are 1502 two-roomed dwellings *i. e.* 23·8 per cent of the whole total with an average of 3·78 occupants to a dwelling. The occupants of the three-roomed dwellings provided by the Cast Steel Works give an average of 5·11 as compared with 5·71 in 1903. In judging these figures, it must be borne in mind that the tenants of houses belonging to the works are forbidden to take lodgers; very near relations of the tenant form the only exception to this rule. We must add the remark that this betterment has not been effected by turning out the tenants in cases of overcrowding, but by providing them with a larger dwelling, for the old rule is strictly observed, of letting families with many children have the advantage of the first chance, since it is always difficult for them to find accommodation elsewhere. This point and the length of service weigh in the letting of dwellings. There will always be a demand for a certain number of two-roomed dwellings, as there will always be a considerable number of small families for whom they are large enough, and to whom the low rent is an attraction.

The exterior aspect of the workmen's houses and of the large colonies of this second period shows remarkable improvement. The plain, bare style of the former period accorded not only with Alfred Krupp's intention to provide for the very urgent need of cheap dwellings, but also with the general tendency of that inartistic time. The resumption of the building of dwellings by the Cast Steel Works in 1890, took place at the dawn of a new era, the requirements of which F. A. Krupp fully recognised. His delicate artistic feeling led him to complete his father's work successfully from an aesthetic point of view. Thus the colonies of Alfredshof and Altenhof were designed, each little house standing pleasantly by itself in its own little garden. Now-a-days, from the artistic standpoint of the present day, we may criticise the buildings in these colonies, with their bay windows and balconies, their obtrusive roofs and turrets, their lack of unity in style; we may call such houses unsuitable as workmen's dwellings, not in accordance with what is required of them, we may say that the general effect is patchy instead of harmonious. Certainly, ideas have greatly developed and improved since those days; there is now more feeling for what is genuine and simple, for an exterior correspondence to interior needs and purposes; more attention, too, is paid to the general effect, detail has been taught to play its subordinate part. Still for those days, when the craving for more beautiful form, the desire to lend more loveliness, more truth to the environment of human life, began feebly and timidly to stir to new life:—for that time, these creations, the Alfredshof and the Altenhof, were really valuable achievements, which encouraged many other attempts and bore good and abundant fruit. With the development of purer taste, the tendency has been more and more to reject the purposeless and unnecessary, to study more and more how to bring the exterior of a house into keeping with its interior purpose, and at the same time by the use of simple means to attain a good effect of form and colour. We have learnt to increase the effectiveness of detached houses by suitable grouping. Rows of houses, which admit of the most varied combination began once more to hold their own against detached houses. In one word:—

the principle of sensible and artistic town-planning asserted itself side by side with the demands of domestic architecture. The Friedrichshof and the modern parts of the Alfredshof and Altenhof are examples of this. The architecture of the workmen's dwellings belonging to the Cast Steel Works looks back over a period of 50 years. Its development both as regards interiors and exteriors, detached houses and colony blocks, faithfully reflects the course of change in this domain, and the progress time has brought with it in Germany; and though much belonging to the past has vanished, still the dwellings of the Cast Steel Works present a perfect picture of half a century of improvement.

Another means of promoting the welfare of the workpeople—one which had been indicated already in the General Rules and Regulations—was the erection of schools for children, and for the instruction, mental improvement and entertainment of adults. During Alfred Krupp's life, times were unfavourable to a comprehensive realisation of these plans. So his successor turned to work in this field with all the more energy. In 1890 the Scholarship Fund was endowed with an annual income of 12,000 Marks. Scholarships are offered to the sons of workmen and foremen, who wish for a good technical training, who possess an aptitude for it, and who have distinguished themselves by good conduct and application. Appeals for these scholarships are submitted to a committee composed of employees and workmen belonging to the factory. The applicant must have worked at least four years at one of the Krupp works, and have attended a continuation school with good results; those who get scholarships are sent, as a rule, to foremen's or other technical schools, in some special cases even to a Polytechnical College. The Housekeeping School, which was established at the same time, aims at giving to workmen's daughters who have left school, practical training in the art of plain housekeeping. Cooking in all its branches—such as preserving fruit and vegetables, storing and purchase of victuals and provisions, cultivation of vegetables for household use—are the principle subjects of instruction; then come the washing, mangling and ironing of house linen, darning and mending as well as every other kind of domestic work. The school is carried on in a large building erected for the purpose near the large colonies; there are a head mistress and three assistant mistresses. The course of instruction lasts four months and is divided into two periods, every two months 12 pupils are admitted, so that 24 pupils are taught at the same time. The cooking course is so arranged that not only what is consumed by the school is cooked, but also a considerable quantity of food for the sick, as well as dinners which are taken out.

Then there are a number of institutions provided for purposes of recreation, entertainment and games. In 1890, the Employees' Casino was built in a nice large garden not far from the works, and made over by F. A. Krupp to the Krupp Employees' Casino Club, which was founded at the same time, and to which a certain number of people not belonging to the Krupp works is admissible. A Foremen's Casino, established in 1894, also helps to promote social intercourse. Several provisions have been made for games and sports. In 1884, F. A. Krupp promoted the foundation of the Athletic and Fencing Club, for which a special building was provided, containing a large gymnasium and fencing-hall, a smaller hall for hygienic exercises, and rooms with slipper baths and shower baths. This club is not restricted to the Krupp employees, but admits other members without limit as to numbers. The one qualification for admission is, participation in some game or sport. A considerable number of lawn-tennis courts have also been laid out near the Casino, for the use of members of the Athletic and Fencing Club.

One of F. A. Krupp's most delightful creation is the Boatshouse, which he had built in 1899, below the Hügel in the lovely Ruhr valley. The house was provided for the Casino

Club, and the Essen Athletic and Fencing Club. The ground floor is allotted to the Rowing Club, which forms a section of the latter, while the upper rooms and the wide terrace commanding a beautiful view of the surrounding wooded hills, are used as a restaurant. Near the Boatshouse there are courts and grounds for lawn tennis and other games,—these are flooded for skating when it freezes;—there is a course for cyclists and equestrians.

Lastly there are two important institutions belonging to 1899, which serve for general culture and entertainment—the Association for the Promotion of Mental and Social Culture and the Library. The "Krupp Association for the Promotion of Mental and Social Culture" is not managed by the firm, but is self-governing and independent in the choice of its managers. Still the firm makes large contributions of money to it, in 1910/11, for instance, the donations of the firm amounted to 29,000 Marks, while the yearly subscriptions of the members—2·50 Marks—only brought in 7500 Marks. The association for the promotion of mental and social culture consists mainly of employees and workmen of the Cast Steel Works, but people who are not "Kruppianer" are also admitted as extraordinary members. The specified object of the association is, the care of general mental culture and instructive entertainment with rigid exclusion of all political or sectarian differences. It strives to carry out this general programme by satisfying the intellectual needs of its members, by rousing and stimulating interests in the fine arts, and by encouraging a spirit of good fellowship. The means employed are evening lectures, adapted to the understanding of the audience, and as far as possible illustrated by slides and experiments, evening entertainments, when music, recitation or amateur theatricals are provided; classes and courses of lectures of the greatest diversity; cultivation of choral and orchestral music and other similar things for which a need is felt. For several years, the association has had its own weekly newspaper:—"Nach der Schicht", which it uses for the furtherance of its work. The management of the association rests with a chairman chosen by the members, and a committee composed of one member to every 50 members of the association. By means of this committee the association is able to keep in touch with the workmen. The current work is entrusted to a managing secretary. The association, which began life with 641 members, now counts 3270, and has in the course of time considerably enlarged its scope; it is now an important factor in the intellectual life of Essen. Besides the work proper to its domain, the association has given valuable encouragement to many other intellectual movements; it prepared, for example, the ground for the establishment of the Essen Museum Society. Its plan of action includes string quartetts, theatrical performances in the Essen theatre, evening entertainments, readings, family gatherings in the literary department, evenings for domestic music, evenings for parents, courses of instruction in book-keeping, mathematics, mechanical drawing, in French and English, and in shorthand; it arranges exhibitions of good and cheap home decorative art, and organises excursions. A number of departments have been gradually formed within the limits of the original association. Recently the association has included provisions for the young in its programme.—The Library Hall was opened on March 1st 1899, after F. A. Krupp had decided to establish such an institution, which was to be placed within easy reach to those employed at the Cast Steel Works for their instruction and amusement. At its opening it contained 8000 volumes, whereas now there are about 82,000. The catalogue includes works on all subjects and branches of knowledge, with the restriction, that purely scientific works, especially those dealing exclusively with professional matters, shall only be purchased for the technical library of the factory, and that all works on political controversy which have a tendency to agitation shall be excluded.

The books are lent gratis to the members of the Cast Steel Works, the rule being that they are returned in three weeks. The library at once became very popular, it was soon necessary to enlarge it considerably; within two years after its opening the number of volumes had risen to 28,000. In the first year of its existence the number of those holding cards of membership was 5500, it is, at present, 20,400 and the annual circulation has risen during the same time, from 94,000 to 604,000. To facilitate the use of the institution, several branch libraries have been provided at some distance from the works, and smaller ones have been opened at the outlying works on the model of the Essen library. These contain a total of 26,400 volumes.

What we have now described shows how loyally Friedrich Alfred Krupp carried out the programme for the welfare of the workmen, which had been indicated by his father's General Rules and Regulations, and how he developed it to a system which comprehended the whole body of those he employed. If we wish to draw a comparison between the work of the two men in this field, we may say, that the father completed the foundations and the rough walls of the building, while the son finished the house and made it pleasant to dwell in. The influence of F. A. Krupp's active work in this field also went far beyond the Krupp works, for what was created here, gave a stimulus to many others, and found imitators in many circles. The fruits of this work of his are a lasting memoral which will hand down to posterity the character and significance of the man far better than any monument of bronze or stone.

# THE WORKS FROM 1902.

A few days after Friedrich Alfred Krupp's death his widow issued the following address:—

"To the Directorium of the Firm Fried. Krupp.

I hereby inform you that, with the death of my beloved husband, my eldest daughter Bertha becomes, according to the testamentary disposition of the late Mr. Alfred Krupp, the father of the deceased, the owner of the entire factory with all its outlying works and branches, and that I have to represent her rights therein until her majority. At the same time, as representative of my daughter Bertha, I confirm in their entirety the powers vested in you, the members of the Directorium by my late husband, as I am fully convinced that you will carry on the business of the firm according to the intention of the deceased and with the same loyalty as of old. I request you, the Directorium, to make this communication known throughout the firm.

Essen, November 22nd 1902. Frau Margarethe Krupp."

As the actual owner of the factory was still a minor, Mrs. Friedrich Alfred Krupp resolved to convert the works into a joint-stock company in accordance with the wish expressed in her husband's last will. The needful preparations were begun, and the approaching change announced to those employed at the works, by the issue of the following notice:—

"To the workmen and employees of the firm Fried. Krupp.

My late husband in his last will determined that—in case his early death left the factory in possession of a minor—his works could only be continued in their present constitution with difficulty. He therefore expressed a testamentary wish that in such a case the factory should be transformed into a joint-stock company. I—as the representative of my daughter Bertha,—shall, with the approval of the Directorium and of the executors, carry out this testamentary ordinance, made by the deceased in his care for the future welfare of his works. The change, however, is not to be effected by the sale of the factory, on the contrary, the shares will remain in the possession of my daughter Bertha, as heiress of the factory. In this way, the works will remain Krupp property, in accordance with my husband's desire. It will always be our earnest endeavour to maintain the former personal relations with the works, the same care for those employed, both staff and workpeople, in the spirit and the intention of the deceased.

Essen, January 28th 1903. Frau Margarethe Krupp."

The conversion was completed by act of notary on the 22nd April 1903, and on July 1st 1903, the company took over the whole of the combined industrial undertakings of the firm Fried. Krupp, with all assets and liabilities. The amount reckoned as tied up capital comprised—according to clause 34 of the statutes—the Cast Steel Works at Essen, with the collieries and iron-ore mines, stone quarries, clay pits, iron works and steamers; the Gruson works, carried on as the firm "Fried. Krupp, Grusonwerk" in Magdeburg-Buckau, the steel works carried on at Annen as the "Krupp Steel Works, formerly F. Asthöwer & Co." and the shipyard and engineering works at Kiel and Tegel near Berlin, known as "Fried. Krupp, Germaniawerft". The statutes declared the object of the undertaking to be:—I. The taking over and working of all the former Krupp enterprises. II. The manufacture and sale of steel and iron, &c. with all the needful raw and secondary materials, the working up of steel and iron, &c. to finished and partly finished articles of all kinds, particularly the manufacture of railway and shipbuilding material and of war material, ships and engines. III. The purchase, erection and working of new concerns, and the settlement of all transactions likely to promote the objects stated under II, and IV, the working of any other enterprise and business of any kind which shall be considered conducive to the interests of the company. The capital of the company was declared at 160 million Marks, divided into shares of 1000 Marks, 4 shares were taken by four persons nearly connected with the Krupp family, the rest were the property of Miss Bertha Krupp. In 1906, the extensions which were being made in the factory required a raising of the capital by 20 million Marks. For the same reason two years later a loan of 50 million Marks at four per cent was negociated with a combine of banks, 20 millions of which were put up for subscription at once, and 5 millions later on. The working board of the company was composed of the Directorium as it then was, the first committee of Trustees was composed of:—privy councillor Gustav Hartmann of Dresden, the retired minister Carl von Thielen, privy councillor August von Simson, and the banker Ludwig Delbrück in Berlin, all friends of the Krupp family.

The headquarters of the company is at Essen, it is registered as the firm "Fried. Krupp Aktiengesellschaft" and the older name "Fried. Krupp" was given up. The oldest designation of the Cast Steel Works appears in the deed of 20th November 1811, which Friedrich Krupp, merchant, made with the brothers von Kechel before a notary; it is "Friedrich Krupp of Essen". When in July 1815, Krupp combined with Nicolai, and turned his busines into a company, the original name of the firm disappeared too, and for a short time "Nicolai & Krupp" took its place. But in the autumn of 1816, Krupp resumed the sole ownership of the factory and did business under the old name again—which in its abbreviated form "Fried. Krupp"—existed until June 30th 1903. Friedrich Krupp always signed for the firm Fried. Krupp, as did Alfred Krupp, while in other documents and in printed circulars or catalogues the forms Friederich, Friedrich, Friedr. and Fr. Krupp exist, Friedrich Krupp most frequently. The firm was entered for the first time in the Commercial Register in 1862 as the "Firm Friedrich Krupp", and it was not till 1887, after Alfred Krupp's death, that his son made an application for the legal entry of the firm as "Fried. Krupp". It was also a long time—not till 1875—before the firm adopted one sole trade mark. The products were at first stamped "Krupp" or "F. Krupp",—quite early "Fr. Krupp of Essen", was often used—and the grade of the steel was indicated by the marks then customary, such as stars, crosses, crowns or squares. In 1875, when the law was passed for the protection of manufactures, Alfred Krupp adopted as a general trade mark the pyramid of three rings representing railway tyres. In course of time this appropriate design of the three superposed circles has become the mark by which the great combine is known throughout the world; it has also become a sign and symbol of the harmonious internal collaboration of the works; as such it is used for the design of the souvenir given to every man who has completed 25 years service there.

In the autumn of 1906 Bertha Krupp was married to the Royal Prussian First Secretary of Legation Dr. Gustav von Bohlen und Halbach, who was at that time secretary to the German Legation to the Vatican, he had previously been attached to the Embassy at Washington for several years and during the Boxer rebellion had been sent to the German Embassy at Pekin. On their wedding day the following communication was made to all the works belonging to the firm:—

"To the employees and workmen of the firm Fried. Krupp Aktiengesellschaft.

On the day of our wedding, which God grant may be the beginning of a happy future, it is our heartfelt desire to greet all those who belong to the Krupp works, and to thank all those who till now have promoted the prosperity of the Krupp undertakings. It will always be our most earnest endeavour to contribute our share towards the future maintenance of the approved traditions in the management of the works. We therefore sincerely re-echo the words addressed by Mrs. Krupp after her husband's early death to the employees and workmen, when the enterprise was transformed into a joint-stock company:—"To preserve intact our personal relation to the factory and to continue the provisions for our people—staff and workmen alike—will always be our great aim and object." For in the future as in the past, it will be our endeavour to preserve the whole combine as personal property in the sense intended by the late owners Alfred and Friedrich Alfred Krupp. And in token that our joy to day is to be shared by our whole community, we place a capital of 1,000,000 Marks at the disposal of the Invalid Fund of the Krupp's Workmen's Endowment, the proceeds of which are by statute to be applied throughout the whole extent of the firm's works. We feel assured that we can rely on perfect trust and zealous collaboration from all ranks and classes of those employed in the factory. Thus it will be possible to maintain the great whole in permanent prosperity for the common good of us all.

Gustav von Bohlen und Halbach
Bertha von Bohlen und Halbach née Krupp."

Auf dem Hügel, 15th October 1906.

The young pair made the Hügel their residence, which remained connected with the works in the same manner as before. In order to keep the name of Krupp in the family Gustav von Bohlen und Halbach asked the Royal authorisation to add it to his own. Permission was granted and notified to the employees and workmen on 17th October 1906 as follows:—"The great honour has been conferred upon me of being allowed to add to my own name, that borne by the founder and promoters of the works and thus to preserve also to my wife her maiden name under which the factory has reached its present greatness. I beg all employed there to consider this as a further proof of the earnestness of our desire:—to be true to the old traditions and to be at one with the works for better and for worse." Krupp von Bohlen und Halbach devoted himself at once to the new duties he had assumed. He undertook the supreme management of the firm and became a member of the Board of Trustees, a few years later, shortly before the death of Gustav Hartmann, the first chairman, in 1910, he took the vacant chair. In 1907 a son was born to the young pair—the first heir of the Krupp name born at Hügel—he was baptised by the original name of his great grandfather—Alfried. The father, in informing the factory of the happy event, expressed the hope:—"May our son, as he grows up in the Krupp works, gain by practical work, the thorough foundation of knowledge needful for the important duties and responsibilities he will one day have to take upon him, duties, the seriousness of which I myself realise more deeply every day." In the name of all those employed in the works the Directorium replied to the announcement with the wish:—"May God grant his blessing to the youngest generation of the Krupp family."

In the ten years that have passed since Friedrich Alfred Krupp's death, his successors have sincerely and successfully striven to fulfil the promises made in these several communications. Mrs. Krupp immediately after her husband's death gave a substantial proof of her active interest in the institutions for the welfare of the workmen commenced by Alfred and Friedrich Alfred Krupp; she presented three million Marks to the provisions for employees and workmen who are past work. She also gave a large sum to the town of Essen, for a Friedrich Alfred Krupp Endowment, the proceeds of which are for general benevolent purposes. Later on, too, the liberality of the Krupp family went beyond the limits of the factory. For instance, a swimming bath has been built in Essen-West, in the middle of the workmen's colonies, and placed at the disposal of the general public. The Margarethe Krupp Endowment, also, provides and lets dwellings for people of small means; its capital is one million Marks and its property 50 hectares; the dwellings built on this estate may be rented by other inhabitants of Essen as well as those employed by the firm. In connexion with this endowment Mrs. Krupp has handed over to the town a considerable stretch of land, consisting of a number of narrow valleys—so-called Siepen—to the south of the town:—she has had paths laid out and trees planted, and has presented the whole to the public as a park.

In the factory itself too, many additions have been made; not less attention has been paid to what already existed, and which was extended to meet new requirements. There was the more cause for this as the whole combine, particularly the Cast Steel Works, had been enormously extending during this period, and a large new establishment, the Friedrich-Alfred-Hütte at Rheinhausen had been built, for which all the Krupp institutions for social betterment, such as provision of dwellings, hygienic institutions, supply stores, pension and aid funds, had to be provided. The following details may be given:—The aid given by the workmen's pension fund has been raised several times, the employees' pension fund at the Grusonwerk has been raised to the level of the Essen fund. Those endowments which chiefly provide for those who are unable to work before they have reached the time of service which entitles them to a pension, amount at present to 10·6 million Marks, as compared to 2 6 million Marks in 1902. Great advance has been made in providing dwellings, in 1902 the firm owned 4300 dwellings in Essen, in 1912 it owns a round number of 6600, including 630 built by private persons and permanently hired by the firm. At the Altenhof many family dwellings, two homes for old people and a number of dwellings specially for widows and a small public bath have been built. At the outlying works—in particular the coalmines and the Friedrich-Alfred-Hütte—there are now 3100 dwellings for workmen and employees, as compared to 1300 in 1902. More lodging houses too, have been built at Essen and at the Friedrich-Alfred-Hütte, so that the firm can now accomodate 2300 unmarried lodgers. In further respects, the buildings have followed the lines described in a previous chapter; a number of new branches have had to be built for the supply stores; the bakery has been re-built and brought up to the greatest efficiency; the butchery department has also been improved to an extent almost equal to new building. The industrial school for grown up girls has also been moved to a new and larger building. The Savings Bank, after having proved its utility at the Cast Steel Works—where it has now 18,000 depositors—has been introduced at the branch administrations, and small libraries, too, have been opened at the outlying works.

Activity in regard to hygienic work has been specially comprehensive. Here we find a series of new institutions which serve in part to assist the families of those employed at the works in an increased measure in matters relating to health and sickness. The firm's hospital at Essen has been added to several times; a hydropathic ward is now being built there. A hospital with 16 beds has been erected at the Friedrich-Alfred-Hütte. A second convalescent home for men has been built at the Altenhof, and a large convalescent home for women, as well as one for children, so that these institutions can now dispose of over 180 beds. A lying-in hospital with 15 beds has also been built. The Grusonwerk was presented with a house of rest for employees, in commemoration of its fiftieth anniversary, the "Margarethenhof" at Wernigerode in the Harz. A boarding house has been set up in the beautiful Sayn valley, for employees of the Cast Steel Works and outlying branches—either on leave or pensioned—; here 40 guests can be received at the same time. Lastly we must mention one of Mrs. Krupp's endowments, the proceeds of which are devoted to providing home nursing or household help in cases of confinement or serious illness among the wives of the workmen, whether the woman be at home, in the hospital, or in the convalescent home.

Before closing this subject we must mention the institution of a general festival held in honour of those who have passed 25 years in the service of the Cast Steel Works. This celebration takes place annually during the second half of February, in memory of Friedrich Alfred Krupp. The Krupp family take a personal part in it, and all who have completed their 25 years' service during the year receive a sum of money and a souvenir bearing the Krupp initials and the three circles. From the beginning of 1910, a factory newspaper —the "Kruppsche Mitteilungen"—has existed. It appears weekly in connexion with the organ of the "Bildungsverein", the society for entertainment and instruction, intended to promote mental and social culture, it is called "Nach der Schicht" (After the Day's Work). It contains the notices of the Directorium, and other authorities, and news from the various parts of the firm's property, which may be of general interest.

What has just been described is sufficient to show that care for social betterment has not retrograded in the factory. After having paved the way for social legislation, the firm is still called on to fulfil a lofty mission. In spite of the increased activity in social work of public bodies and communities and societies, the co-operation of the industrialist is still indispensable, because neither the State, nor the parish, nor any one else can do exactly what is necessary and desirable. Besides public social measures must always hold a middle course, whereas the industrialist of to-day—finding the most pressing social evils already removed by legislation—can go beyond this middle course, and become the promoter of progress and culture. In this point the management of the Krupp works holds fast to the words which accompanied a printed volume dealing with the Krupp institutions for the welfare of the people:—"The managers will adhere to the traditions established by the founder of the factory, and continue to support every measure which aims at the intellectual, moral or physical good of the workmen; they will be ready to make any sacrifice, irrespective of the gratitude or ingratitude they reap, only actuated by a sense of the employer's duty to keep his hand and heart open to his loyal workpeople. May the fulfilment of this duty long promote the prosperity and continuance of national industry."

The industrial advance of Germany which so greatly favoured the Cast Steel Works under Friedrich Alfred Krupp's management, has on the whole continued to do so after his death—the last ten years of their century of development. The signs of improvement in trade which began to appear during the Düsseldorf Exhibition of 1902 were not illusory; five years of steady advance in the German iron trade followed, which at first depended on the needs of the home market, especially the increase in railway building and traffic, and since 1905 on foreign orders. Till the end of 1907 all the works were provided with plenty of orders at good prices. The junction of German industrial forces in great combines, which make it their duty to fight shoulder to shoulder, instead of weakening themselves by aimless competition, continued to gain ground, and it has not failed of its compensating effect during the inevitable fluctuations of the international market. First a number of small syndicates were formed in the iron industry, certain of which were absorbed into the "Stahlwerks-Verband", the steel works union founded in 1904; this combine now regulates the greater part of German raw-steel production on uniform lines. The formation of this combine is one of the most important events of modern times for the German iron market and with the Coal Syndicate, for the whole of German industry; considering the ever increasingly keen competition between iron-producing countries; and it has not failed to influence the international iron market. It is owing to this, and other smaller syndicates, that the necessary enlargement of the factories was not carried out unduly during the last period of great prosperity, the evil consequences were thus avoided which might have followed a temporary reaction which checked the rapid advance of 1908. This reaction was, however, less long and less severe than previous ones had been, it gave place to normal conditions in the second half of 1909, and these conditions have developed satisfactorily in the subsequent years. Thus the line of advance followed by German industry, which formerly deviated so suddenly upwards and downwards, has begun to show a decided tendency to remain at a more uniform level in recent times, and the leading firms—among others the Krupp firm—may claim a certain share in this result, which is important alike to the healthy economic life of the whole nation and to the wellbeing of the working classes. Moreover Krupp's participation in these two great syndicates could not but influences his status in German industry. By its traditional part in the supplying of ordnance and armour the firm had always held a unique position among the great German steel works, and this position had been strengthened by the increase of the German Navy, the enterprise had also—since 1905—been placed on a far wider footing than formerly by the adoption of the Thomas process at Rheinhausen and the manufacture of rolled products en masse, also in the domain of products for transport and other industries, the so-called peace material. Hitherto it had been a work of well-established historical repute, famous in certain branches of steel production and manufacture; now, impelled forward by the demands of modern times, it became with one mighty stride a great combine in up-to-date ingot-steel industry, and as such holds its own against other works of the kind. The rapid development of the Friedrich-Alfred-Hütte, which we are about to describe, must be looked at from this point of view. But the stride which carried the Cast Steel Works out of the special domain of highly valued products into the wider world of manufacture en masse could not but involve other consequences, which have influenced the course of its latest development. We have already said that the Friedrich-Alfred-Hütte takes more than half the coal consumed in the Cast Steel Works and all the branches. Foreseeing this the new collieries we have spoken of were purchased after 1899, to supply the increasing demand for coke, and coke ovens were erected there with all appliances for bye products, so that in 1904 the Hannover colliery began to deliver coke and in 1908 Emscher-Lippe. But coke has still to be bought in varying quantities to meet the ever-increasing needs of the blast furnaces at the present times. The adoption of the Thomas process has occasioned a higher demand for phosphoric ores since 1905 and a considerable change in the Cast Steel Works' ore requirements. Part of this altered demand can be supplied from the Lorraine mines, which had been opened up in the meantime. Some of the phosphoric ores obtained from the earlier purchased Lahn mines now rose in value, but still great quantities of ore have to be drawn from the seams of magnetite rich in phosphor in Sweden and Lapland, and other foreign mines too furnish a considerable part of the present demand. In order, however, to uphold the important principle of independence in this respect as far as possible, the firm has recently continued to purchase iron-ore mines. In 1906 the phosphoric iron-ore mines then owned by the Prince of Solms-Braunfels, on the Lahn, were bought by Krupp; in the following year the Bieber mines at Gelnhausen, which yield ores rich in manganese.—The firm's position as iron and steel works not only influenced the provision of raw material, but also the finished manufactures, for it was absolutely necessary to become more competent in the production en masse in steel. One step towards this was made in 1911, by a contract with the Westphalian Wire Industry, which assured to the Krupp firm the preponderating position with that company. To supply the demand of these works with rolled wire, a wire-rolling mill is now being built at the Friedrich-Alfred-Hütte. It is historically interesting, that thus—after 100 years—a goal has been reached which the founder of the works set before him in the first years of his activity, and for the attainment of which many measures had been taken by him and his successors.

The great improvement of trade which set in in 1902 is, as was said before, closely connected with the rapid building of the Friedrich-Alfred-Hütte, which during the next five years engrossed the largest share of the firm's resources and attention, and therefore must be described first. In the short interval between making the programme of enlargement and executing it, the demands of the steel market rose so greatly that when building was started, a much larger Thomas plant had to be provided for, and the plans amplified accordingly. The erection of the three new blast furnaces was so vigorously pushed on, that the third could be blown in in July 1905, and the whole new plant started. The new furnaces have a capacity of 600 cubic meters, and a daily output of from 450 to 500 tons of Thomas iron, the older smaller furnaces are now used for smelting Bessemer pig and hematite. The port was also extended to correspond with the blast furnaces, and the unloading efficiency raised by new handling appliances. To supply the demand for coke, two sets of 60 coke ovens each were built near the blast furnaces, which can yield 200,000 tons of coke annually. To these ovens are annexed all the plant required for bye products. All the coke-oven gas, that is not required for the ovens themselves, and that from the blast furnaces, which is left over the general purposes, is used for lighting and power generating purposes, and this comprehensive utilisation of waste gas imparts to the Friedrich-Alfred-Hütte much of its special aspect.

During the time that elapsed between the beginning of the extensions and their final completion, the blast-furnace gas engine had begun its triumphant march through the world, and it was adopted in the new works in every department to which it was suitable. Eight more powerful gas blowers were added to the older ones worked by steam, the yield of the former being 1000 cubic meters each per minute. The electric central power station —of about 5000 horse power—and some of the rolling mills were also driven by gas engines. As the steam power which is still preferred for some purposes is also produced by heating the boilers with the furnace and coke-oven waste gas, while in the open-hearth shops a mixture of the two is used instead of generator gas, and the rolling-mill furnaces have been provided with blast-furnaces gas heating, the direct use of coal as fuel has been almost given up. This use of blast-furnace gas of course implies a thorough previous purification, during this process a quantity of dust, containing a good deal of iron is deposited in the dry cleanser; this dust is worked up into briquettes for further use in the blast furnaces.

While the blast furnaces were being built the Thomas steel plant was hurried on as much as possible, so that it could be started in January 1905, and brought to the projected productive capacity in a few years. The steel work has five converters, each of 25 tons capacity, which receive the liquid pig iron from the great 900 ton mixers in which the produce of various blast furnaces and various tappings is blended. The liquid mass is conveyed from the mixers to the converters in electrically driven ladle trucks, the finished steel is taken to the adjacent foundry by an electric-hydraulic casting truck, and then cast into ingots of from 4 to 5 tons. The older open-hearth shop which had also been fitted for working up liquid pig iron continues work as well as the Thomas shop, larger furnaces were put up there in 1907. It now has three furnaces, each for a charge of 35 tons and three for 45 tons, which work up ~~part of one pig iron~~ produced at the Friedrich-~~Alfred-Hütte.~~

The ruling idea in the rolling mills at the Friedrich-Alfred-Hütte is to carry on the whole manufacture from the raw material to the finished article without stopping to re-melt; and as far as possible without re-heating the intermediate products. This idea has been completely put into practice. As soon as the steel ingots have solidified they are taken by a steam locomotive from the foundry to the rolling mills, and there placed in Gjers pits, some of which are heated and some unheated, to bring them to a uniform temperature; they are taken out as required and laid on the rolls. The process of rolling begins with the big blooming mill with rolls of 1150 millimeters diameter, one of which has existed ever since the works were built; a second was added when the extensions were made. Each mill is driven by a twin reversible steam engine of 7000 horse power. Here the ingots are rough rolled, and then either got ready for sale, or immediately worked up into heavy girders, rails or billets. This working up is done by means of two heavy mills, with rolls of 850 millimeters caliber, which are driven by the biggest engines of the works, of 16,000 horse powers. A great number of other mills, some driven by steam, and some by gas motors, of from 1500 to 2600 horse powers, serve for the further treatment of the steel for sections, bars and round iron, sleepers and other products.

The demands which the general advance of trade and commerce made on the new plant soon after its completion, necessitated more building during the years that followed the opening of the works. The first building programme had hardly been completed when the extensions became necessary. First the working plant of the new blast furnaces was augmented by adding to the number of hot blast apparatus, in 1907; and again in 1908, a new blast furnace was started. Then the old blast furnaces were raised to the height of those more lately built, and again in 1911 a new blast furnace—the ninth—was put in blast. Thus the power of the works has been raised to an annual possible output of 1,200,000 tons of pig iron. The actual output of the working year 1911/12 was 1,000,000 tons, the greater part of which was worked up in the Thomas steel plant. The building of new blast furnaces and the increased efficiency of the older ones of course involved a strengthening of the engine plant for the blast furnaces and a great enlargement of the steel works and mills, and the auxiliary shops. Big gas engines have been adopted in almost all the extensions made in these latter years. For example, the sixteen blowers employed for the blast furnaces are all driven by gas motors, while the older steam driven blowers are kept in reserve. In the electric power station too, only gas dynamos are at work, the older steam dynamos are in reserve.

The history of the Friedrich-Alfred-Hütte is a striking proof that very comprehensive plans must be made when such a large enterprise for production en masse, is projected, —both as regards the space and the laying out—at least if one is not to exclude the possibility of meeting demands which may arise in a distant future. By not allowing the question of immediate profit to hurry the establishment of the fresh enterprise, until the question of site was settled satisfactorily and liberally, the necessary future extensions could be provided for, and the undertaking firmly based for a long time to come on the footing intended by the first programme.

The share of the various ways of making steel, in the aggregate production of the Cast Steel Works, has changed during the last quarter of a century.—Puddled steel quite disappeared with the pulling down of the last puddling furnaces in 1910. The figure reached by crucible steel—which after a hundred years' experience is still the best and most reliable, and indispensable for many purposes—has risen greatly, so that the productive power of the crucible-steel plant has had to be increased several times, even quite lately, by adding to the crucible-making shop. The use of open-hearth steel has, however, relatively risen more, for in proportion as it has been perfected chiefly by the adoption of the basic process, it finds ever-widening markets. The rapid enlargements of the Krupp open-hearth shops from 1887 till 1900, already described, when five plants some of very considerable size and for the most varied purposes, proves that the importance of this department was never lost sight of. The existing shops have quite recently been adapted, as far as possible, to the growing demands, by making additions to them. In 1905, for instance, a considerable extension of the then largest shop Martin work V, was undertaken to meet the increased sale, and especially large orders for billets for tube making; five new furnaces, each of 30 tons capacity, were set up that time. But for a long while a want has been felt for a big shop, which could supply all the factory's requirements for steel castings, which have obtained such a wide field of application in recent times. The old steel foundry in the crucible-steel shop and the open-hearth shop I had to make all that the factory wanted in this line; the latter shop had been enlarged by an annex in 1895, but it was now strained to its utmost power. The buildings used as a steel foundry had in part been put up for other purposes, and therefore were not adaptable to the changes necessary for modernizing them in the deserved manner, such as erecting, hauling and transporting appliances. Nor did they contain the needful space for carrying out the various processes in the proper consecutive order. The work of trimming, casting, cutting and knocking off runners, of annealing, had to be separated, as steel casting increased, which wasted time and expense for transport. These old shops were in fact a makeshift which could not be used much longer. The new open-hearth shops, again, had their own special work, and could not come into consideration for the purposes required. These combined reasons pressed for the erection of a large new steel foundry on a uniform plan, which would satisfy all the necessary conditions for making and finishing the castings in the cheapest manner and the shortest time.

The space where the first rolling mill for plates and the repairing shop III—for which new building had been put up—had stood, and also the ground of the old laboratory was taken as site for the new steel foundry,—open-hearth shop No. VI,—it was built and started in 1910. The rule observed in the plans was, as far as possible, to substitute machine work for manual labour and to avoid all needless transport to and fro, by carrying out the processes consecutively in the same shop. Therefore great importance was laid on equipping the new building with a great number of travelling cranes. It is remarkable as a deviation from the ordinary rule followed in building, that two electric cranes of 25 meters span bring the molten steel across all the bays of the shop, so that it can be cast not only in the furnace bay but also in all the others, which obviates the necessity of transporting all the moulds to the furnace bay. Open-hearth shop No. VI is one enormous room, 207 meters long by 90 wide, in which the moulds can be made and baked, the metal can be cast, trimmed and the runners knocked off, and lastly the reheating, finishing and loading up of the finished castings can follow one upon the other. The beating down of the mould sand and the finishing of the castings can be done in every part of the hall by means of pneumatic tools, fed by a compressed air system; this also is a great saving of time and labour. The steel is produced in four open-hearth furnaces of 28 tons each, and in one small Bessemer plant. The latter serves for the production of small pieces thin in metal. The steel foundry is reckoned for a yearly output of 20,000 tons of finished castings. A set of ten generators supplies gas for heating the furnaces.

This foundry with its great extent and modern equipment will in all likelihood be able to supply the demands of the firm and its customers, for a long time to come, and so the old open-hearth shop No. I could be relieved from further work at steel casting. Now the long desired alterations could be begun in this important plant, which had only been deferred so long because no proper substitute for it could be found. The furnaces of 10 tons each, which had been built at a time when it was believed that larger furnaces would not yield the requisite uniform product, were still working; they were much more costly to work than the newer ones. Both space and equipment were inadequate for the various purposes to which by degrees the shop had been put. The casting pits were of a kind that made it impossible to fit the moulds with the appliances—described elsewhere—to obtain dense castings, which had long since been adopted in the crucible-steel shop. The space under the furnace, where indispensate work at the valves and generators must be done, was too restricted and the working was difficult and costly; there were hardly any sheds for the proper storage and working of raw materials. But now the whole shop was modernized in the fullest acceptation of the word. There are now two spacious casting bays adjoining one another, in each of them a long row of open-hearth furnaces, in front of these are the casting pits, which are served by special cranes, and afford sufficient room both for small castings of a uniform kind, cast in teams, and for the largest castings which sometimes weigh as much as 100 tons. The existing cranes can lift weights up to 130 tons. Radical alterations have been made in the room for the generators and valves. The furnaces, unlike those in the open-hearth shop V, are built on a level with the floor of the foundry, so as to simplify the charging, but under each row of furnaces, there is a large through-going valve vault, with ventilation and electric light, where all that is necessary can be done at the generators and valves, the bricks can be brought in, and the slag removed. A big storage yard with electric travelling cranes and lifting magnets serves both for the storing of scrap and other materials which are not used immediately, and also for the finished castings until they are sent off, and for keeping the moulds which are not in actual use in the foundry. We must also mention that the new open-hearth shops are quite up-to-date in regard to the conveniences they provide for the men, such as washing and dressing rooms and dining halls, lighting and ventilation, which of course the older shops do not possess. At present the Cast Steel Works has 42 open-hearth furnaces at Essen, with a total capacity of 1025 tons, to which must be added 13 furnaces with a total capacity of 315 tons at the Friedrich-Alfred-Hütte, the Annen steel works and the Grusonwerk.

While the production of open-hearth steel was increasing, that of Bessemer steel was decreasing considerably, after the manufacture of rails was transferred to the Friedrich-Alfred-Hütte. Thus the cost of producing Bessemer steel rose, and placed it at a still greater disadvantage in comparison with the open-hearth steel produced in the big modern shops. In spite of this a certain amount of Bessemer steel is still made at the Cast Steel Works, as there is always a large circle of customers for this specially pure product; it is much used for piano strings, umbrella wires, needles, &c. as well as for knives, forks, files, saw blades, and such things,—its production therefore had to be continued. In 1911, with a view to lessening the cost of production, the Bessemer shop underwent alterations which permit a more rational and suitable process of production. By the erection of new cranes and casting pits, the steel can now be cast in small ingots, which can be worked up directly in the billet-rolling mill, therefore the rough rolling formerly employed could be given up.

Among the newest plant for steel production in the Cast Steel Works we must not omit the electric-steel plant. Steel-making in electric furnaces, which at first only seemed to be possible in countries possessing a great deal of available water power, attained a certain importance for all countries after the discovery that electric furnaces could yield grades of steel which might rival with crucible steel in value and resistance. The Cast Steel Works, accordingly, devoted some attention to this process; in 1907, experiments were started with the induction process, as this resembled most nearly that used for crucible steel, the point in question being to produce a steel as near as possible equal to crucible steel. A Frick induction furnace was first employed. This system proved most useful for the purposes of the factory, and moreover very satisfactory from an economical point of view. The firm, however, went on to experiment also with an electric furnace on the Girod system, in 1911. As it only seemed possible to judge the utility of the new processes from the qualities shown by big castings, all the furnaces were built, from the first, of the largest possible capacity; at present the electric-steel works contain two Frick furnaces of 10 tons each; and a Girod furnace of 12 tons. There is a special electric-power station for the Frick furnaces, with two 1200-horse power steam engines, and two alternating current generators, for 950 kilowatt and 5000 volt. The Girod furnace has till now been fed from the central power station by a three-phase alternating current of 5000 volt and up to 1200 kilowatt, but it is about to be provided with a turbo-generator, which is being erected in the new electric power station. The products of the electric-steel shop are chiefly used in gun making, but also to a certain extent for tool steel, railway material, &c.

Most of the extensions of plants for rolling and forging steel made in the last ten years, have been touched on in the description of the departments to which they belong. In many departments the generous provisions made in early times obviated the necessity for new plant, or reduced it to a minimum, some plants could be quite stopped, pulled down, or put to other uses, after their work had been made over to other departments, chiefly to the rolling mills of the Friedrich-Alfred-Hütte. Thus the fish-plate and billet rolling mill, which since 1883 had delivered great quantities of finished and half-finished products for railway and shipbuilding, were pulled down when the works at Rheinhausen were finished. The rolling of spring steel which had been done in that shop too, was now transferred to the blooming mill in the puddling shop, which had space for other work now that puddling was being gradually abandoned. For the manufacture of wheels and wheel tyres, a disc-wheel rolling mill of large size, a finishing and rough-rolling mill have been added to the older plant. The rail-rolling mill built in 1864, and altered for the last time in 1903/04, had during the last ten years of its existence not only made rails but also round and square steel bars; in 1906 rail-making was quite given up at Essen and handed over to the far more efficient rail-rolling mills at the Friedrich-Alfred-Hütte. During their existence the Essen mills had rolled a total of 2,800,000 tons of rail. The old rolling mill underwent a thorough alteration and now serves for the production of billets and the round steel bars used for seamless tubes, for rolling special steels used in engine and motor car building, and in the wire industry, &c. A great part of the steel used in the factory is brought to this shop to be treated by its complete up-to-date equipment.

The use of the forges at the Cast Steel Works, which Alfred Krupp had enlarged with special care, has been restricted in a certain measure of late years; part of their work has gone into the rolling mills and presses. But to compensate for this the forging presses have been greatly extended. In 1908 new plant for this purpose was put up in the pressing plant II, the so-called "Pressbau II", which had been built out on the space left by the two old giant hammers "Fritz" and "Max", which were pulled down in 1911. Pressing plant II now contains four big forging presses of 2000 to 4000 tons pressure, and is well supplied with all requisite auxiliary plant. Here steel castings of upwards of 100 tons weight and 4 square-meters section are forged for gun tubes and hoops of the heaviest calibers, for marine shafting, crank shafts, turbine shells, cylinders for big presses, and such like; and those hollow bodies which have a diameter great in proportion to their thickness of metal, are treated by a hollow forging process which can be adjusted to the length and breadth of the object in hand. A hollow is punched in the rough-forged massive ingot, this hole is widened by stretching over a mandrel until the diameter and thickness of the walls are brought to the required dimensions. Ingots of great length are worked by punching out a core according to a patented process. Thus the Krupp factory can produce hydraulic cylinders, gun hoops and jackets up to 20 meters in length, and hoops up to 5 meters in diameter, and turbine shells up to 3·5 meters in diameter and 5 meters long. All the presses in this department are driven by the steam-hydraulic system, by which a pressure of 7 atmospheres from the boiler is transformed by a steam driven apparatus into an hydraulic pressure of 450 to 600 atmospheres in the press cylinders. The no-load work is effected by an hydraulic pressure of 120 atmospheres by means of pumps and accumulators worked by weight. The stroke of the presses can be adjusted to any required measure. There are two cranes to each press with a hauling power of 80 and 100 tons, and four heating furnaces of the biggest kind. The waste gas from the furnaces is used to heat a set of boilers which supply most of the steam for pressing plant No. II.

An account has already been given of the greater part of the changes which have been made up to the present time in the shops for manufacturing industrial products. Of course all these departments have been much enlarged recently. So, for example, the mounted wheel and railway shops have been greatly raised in efficiency by additions and extensions, and in every case the greatest attention has been paid to distributing the work in the most suitable way, which of course in the day of small things was not possible. Other departments have been entirely rebuilt and modernized, and the older shops with their limited space given up, for instance the spring shop, rebuilt in 1905,—again other shops which had grown too small for their original purpose have been taken for other work for which they quite suffice. Among these is the apprentices' workshop, which since 1908 has been in a large three-storied building formerly used as a projectile turning shop. Here the young smith and turner apprentices get their first training under the supervision of skilled foremen and workmen. The first story of this shop has a number of benches with jaw-vices for locksmiths; and in the second story there are 155 machine tools, such as lathes, tools for boring, planing, slotting and shaping, for turners. In the ground floor there is a smithy with ten forges and a tool-hardening shop. The smith apprentices stay a year in this shop, and the turners almost two. Then they are sent on to the department workshops to be further trained. About 300 smiths and turners are instructed every year, the number in the shop averages 400. The whole is under the control of an engineer whose sole occupation is to attend to the work and instruction of these youths.

Far greater revolutions have taken place in the shops for making war material, by building new shops and modernizing the old ones for guns, gun mounts and carriages and other such products. On the one hand, demands far greater than were foreseen, were made on the Cast Steel Works at the beginning of this century, by the rapid advance in gun building, especially caused by the enlargement of the German Navy, and the raising of gun calibers; on the other hand, the latest technical improvements made it always less possible to manage with the old equipment. This caused many alterations and new buildings, which have brought on a great change in the well known picture of the Cast Steel Works; changes which have certainly made a radical difference in the expedition and economy of labour. The resources and methods of work in the shops have been fundamentally reformed during the last twenty years. The adoption of new machine tools for special purposes, the rapid spread of automatic machines which incessantly reproduce the same part almost without the workman's interference, the extensive adoption of milling tools in many places where planing or slotting machines were formerly used, the substitution of grinding machines for lathes in finishing the heaviest pieces, the already mentioned rapid-steel tools, and the use of electric motive power instead of the old clumsy transmission:—all these things have brought about changes and new erections in workshop equipment which frequently could not be carried out within the former limits of space. The use of rapid steels demanded quite new machines provided with cooling apparatus to counteract the increase of heat, and also for getting rid of the mass of steel chips produced by the rapid treatment. The steel chips in the two biggest shops of the Cast Steel Works, mechanical workshop IX and gun shop XI amount to 25,000 kilogrammes daily, and special loading and transport appliances are provided for their removal.

The necessity for carrying on the mechanical work consecutively and with a consistent division of labour, and for avoiding as much as possible the loss of time caused by the transport of materials, was another reason for modernizing the shops. The older ones, which at need had been used for the most various purposes to help one another out, could not be altered to the new method of working. At the same time the rise in wages and in the price of raw materials, made it necessary to regulate labour more thoroughly and to do away with all auxiliary details which could be spared. This was an undertaking of no common difficulty, considering that the Krupp works, for more than half a century, had been growing and expanding as momentary needs required, and as far as the available building space allowed, from small beginnings, sometimes from temporary makeshifts. Space did not allow of old shops being enlarged to meet the present requirements, or of the combining of those which lay too far apart. It was unconditionally necessary to erect new buildings on new sites for whole branches of produce, before the old scattered shops could be pulled down and room made for others. By degrees, however, the projectile and fuze manufacture, the iron and projectile foundry, the carriage building, and other special shops were assembled in modern spacious groups. The fuze shops were completed in 1903, as a large self-contained department, which has again been enlarged quite lately, and is at present equipped with 575 machine tools. The German Emperor honoured this interesting department with a visit in 1906. The projectile-turning shops, which were formerly scattered in various places, were grouped into one department in 1907. This consists of three big buildings, with narrow gauge railway and electric suspended railroad, also with electric lifts, and has a shop area of 16,000 square meters. About one and a half million projectiles of all sizes and kinds are turned out annually here, by 850 machines. Large spaces have been opened in the older parts of the works by these new buildings, spaces which could be utilized for new shops or for enlarging inadequate old ones; but in all cases the combination of consecutive operations and the avoidance of unnecessary transport is taken into account. In some cases old workshops which adjoined one another have been turned into big modern ones, by erecting the new shops round and above them, so that the department did not have to stop work while it was being reconstructed. Thus in 1911, gun shops I to V, and the mechanical workshops II and III,—built in the 'sixties and 'eighties—were by alterations and new buildings transformed into one huge edifice:—the gun shop No. I, with up-to-date equipment. Here all the parts of gun tubes for medium calibers are made and fitted, while the manufacture of small tubes for field guns and light howitzers has been combined in gun shop IX, built in 1906/07. This last is a four-storied building, in which the machining of the tubes proceeds systematically from the ground floor upwards, while the breech mechanism parts are made in the third story and the fitting of the finished tubes in the second story. But all the resources at command were inadequate, when the increase of the Fleet, laid down by the Navy Addition Bills of 1906 and 1908, and the armament of the big German battleships had to be provided for. The punctual delivery of the guns and armoured turrets for these ships involved the speedy erection of one special shop for making the heaviest tubes, and another for the mounts required for them. Only thus the indispensable division of labour in the gun-building department, and the desired relief of the factory plant could be effected. Both shops were designed, in 1906, on the largest scale ever taken for such buildings, nevertheless they have had to be considerably enlarged since. Gun shop XI, which is exclusively used for making tubes of the biggest calibers, consists of a cross bay and three long bays of different lengths, the longest of 200 meters, altogether the area covered is 21,000 square meters. A shop for shrinking-on the hoops is connected with this. The tools, some of which are the biggest of their kind existing, are driven each by its own electromotor. The handling of the parts in the shops is also done by electric cranes and lifts. The division of labour is so organised that the pieces brought in, go systematically forward, until they are finished and fitted without any transport to and from other departments. Mechanical workshop IX, destined for building the mounts required for these guns, and armoured turrets for the heaviest naval guns, is far larger than the huge gun shop. Its two biggest bays with their deep pits for erecting the armoured turrets measure 250 meters in length and 24 meters in height; its nine bays altogether cover a useful area of 35,000 square meters. It is among the biggest workshops in the world, and its exterior is one of the most noticeable edifices in the Cast Steel Works. It contains more than 470 machine tools on which every part down to the very smallest, can be worked. Among these tools are a number of automatic machines, and also machines of the heaviest caliber, such as the very big platform lathes, of 292 tons weight and 12 meters useful diameter, and the big planing and milling machines. The shop also contains a dining room for 300 men with steam-heated cupboards, baths with 36 shower baths, and washing and dressing halls for 1900 workmen. Mechanical workshop VI—built in 1894 and enlarged several times since—helps mechanical shop IX with building big gun mounts. The small and medium mounts and the corresponding tubes are distributed among certain shops connected by railroad lines with the gun shops which require them. Also the manufacture of all other accessories for ordnance and outfit has been regulated on uniform principles.

By this comprehensive re-organisation of the entire manufacture of war material the introduction of modern improvements in the building and equipment of shops was made possible, the same as it had been in the forges and steel plants described before. All these newly erected and altered buildings present the advantages resulting from iron structure, *i. e.*, the resistance to mechanical influences, especially to the sinking of the soil caused so often in and near Essen by coal mining, the light walls offering greater facility for making big windows, well-ventilated space where treatment and handling can be regulated economically, and finally the practicability of adding to such erections when necessary. Work itself has been simplified by the adoption of the best electrically driven machines and means of transport, with their increased speed and efficacy. One electromotor for each machine now enables individual machines to be kept going without setting the whole transmission in motion as was formerly done. The biggest machines are driven by several electromotors with proper precautionary provisions for the prevention of accidents or ruptures to the costly tools, in case of hitches in the work. Special tool-making shops are attached to the biggest shops, which utilise the experience gained in each department as quickly as possible. Supervision, too, is greatly simplified by the size and arrangement of the halls, and the grouping together of inter-dependent branches, and work is expedited and cheapened by the gain of all the time formerly wasted in moving the work from one shop to another.

The administration side of the factory could not remain un-influenced by this tendency to concentration. In 1905, preparations were set on foot for a new chief administrative building, which would admit of centralising all the management, all the commercial departments and the technical and draughting offices. Of course, the only place for the new building was, like that of the older one, in the centre of the factory. But there was —as we said before—no available space there, until mechanical workshop I was moved, therefore the building was not begun till 1908, and only finished in 1911. The spacious edifice with its massive tower rising 60 meters above the main entrance, is in the Altendorferstrasse, where the life of the factory pulsates most strongly. The bulk and weight of its form lend effective expression to the idea that it is the centre and focus of this busy realm. The new administration building and the adjacent older one, in which now all the offices for the designing of ordnance are placed, are united by a covered passage at the level of the first story. So at last the long desired centralisation of all the administrative forces could be effected, and this achievement is what specially characterises the last period of the Cast Steel Works' evolution and distinguishes it from all former periods. A certain renewal of youth and strength, such as is indispensable now and then in an economic community which has been existing for a century, has been happily effected by these changes, they stand for a pledge that the Cast Steel Works will adapt themselves to all the reforms which time with its ceaseless changes—technical and commercial,—will render advisable for their prosperity.